BOLT BERANEK AND NEWMAN INC

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FABRICATION AND TESTING OF ACOUSTIC SENSORS FOR BOUNDARY LAYER FLOW TRANSITION DETECTION

Byron E. Blanchard
David E. Johnson
Klaus Kleinschmidt
Edward A. Starr

August 1969

Prepared under
Contract No. NAS1-8472

by

BOLT BERANEK AND NEWMAN INC.
50 Moulton Street
Cambridge, Massachusettts 02138

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA CR-66801

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TABLE OF CONTENTS

page

LIST OF SYMBOLS iv

SECTION 1. INTRODUCTION 1

2. SYSTEM DESCRIPTION 2

2.1 Acoustic Coupler. 2

2.2 Sensor. 6

2.3 Signal Conditioner. 9

3. PERFORMANCE REQUIREMENTS 13

3.1 Sound Level Prediction. 13

3.2 System Performance. 20

3.3 Environmental Requirements. 21

3.3.1 Operating environments 21

3.3.2 Non-operating environments 22

4. TEST PROGRAM 23

4.1 Engineering Performance Tests 23

4.1.1 Sensor 23

4.2.1 Conditioner. 23

4.2 Quality Control Testing 23

4.3 Qualification Testing 34

4.3.1 General. 34

4.3.2 Shock, vibration, and acceleration . 35

4.3.3 Temperature and altitude 37

4.3.4 Re-testing 38

5. CONCLUSIONS. 39

REFERENCES 40

APPENDIX A A-1

APPENDIX B B-1

APPENDIX C C-1

List of Symbols

Re_δ	local Reynolds Number
f_{peak}	peak Frequency
U	Free stream velocity
δ^*	general boundary layer displacement thickness
FPL_{OA}	overall fluctuating pressure level (dB, re. 0.0002 dyne/sq cm)
FPL_T	transition fluctuating pressure level
q	dynamic pressure
V	velocity
M	Mach number
sub-script ∞	Free stream
sub-script δ	boundary layer
P_{stag}	pressure at stagnation level

1. INTRODUCTION

The fabrication and test of seven acoustic transition detector systems has been accomplished for use in the Pacemaker Materials Technology Experiment. These systems are designed to measure the location and level of the turbulent pressure that occurs during and following the transition from laminar to turbulent flow in re-entry.

To measure these factors, a small rugged pressure transducer is ported to the boundary layer. This transducer must have thermal protection and low sensitivity to vehicle vibrations yet must achieve a broad bandwidth acoustic measurement. Appropriate signal conditioning equipment then follows the transducer. The techniques used to achieve these goals were developed and tested supersonically by BBN under sub-contract NAS 1-7439.

Under the contract NAS 1-7439, a series of development tests were conducted to establish the validity of the porting of the transducer to the boundary layer. These tests included: (a) supersonic wind tunnel experiments to establish that the small porting hole did not prematurely trigger transition; (b) an arc test to establish that the configuration did protect the transducer from the thermal environment and that the hole did not clog; (c) anechoic chamber tests to establish the response of the port under no flow conditions; and (d) supersonic wind tunnel tests to establish the port response under supersonic flow.

The results of these development tests indicated the practicality of the approach. In addition, these and other experiments demonstrated that the port response is more highly damped under supersonic flow when compared to anechoic chamber tests. Specifically, tube resonances that predominate in the no-flow tests are totally damped in Mach 3 flow[1].

2. SYSTEM DESCRIPTION

To measure the pressure fluctuations associated with boundary layer turbulence during and after transition, a porting arrangement couples the pressure fluctuations to the transducer, which then converts the acoustic energy to an electrical signal. This electrical signal is conditioned to the desired input to the data retrieval system. Transducer and signal conditioner are shown in Figs. 1 and 2.

2.1 Acoustic Coupler

The acoustic coupler provides a path between the boundary layer at the surface of the vehicle and the diaphragm of the transducer. The porting arrangement protects the transducer from the severe temperature environment at the surface during re-entry, yet avoids distorting the acoustic input to the sensing element over the frequency range of interest. The port must be flush to the outer surface of the vehicle, so that it will not disturb the flow and thus generate self-noise or premature turbulence.

The coupler configuration is illustrated in Fig. 3. The basic design includes a 1/16-inch inside diameter tube with a right angle bend leading to the 1/4-inch diameter transducer. The total length of the port depends on the heat shield thickness at the measurement location on the vehicle. The minimum total length (without heat shield) is 0.47 inches. The maximum anticipated length is 1.57 in., i.e., a heat shield thickness of 1.10 in.

The resonant frequency of the fundamental mode of the tube is governed by its length, as in a stopped organ pipe. Hence, the resonance is approximately inversely proportional to the heat shield thickness. The small cavity in front of the microphone diaphragm

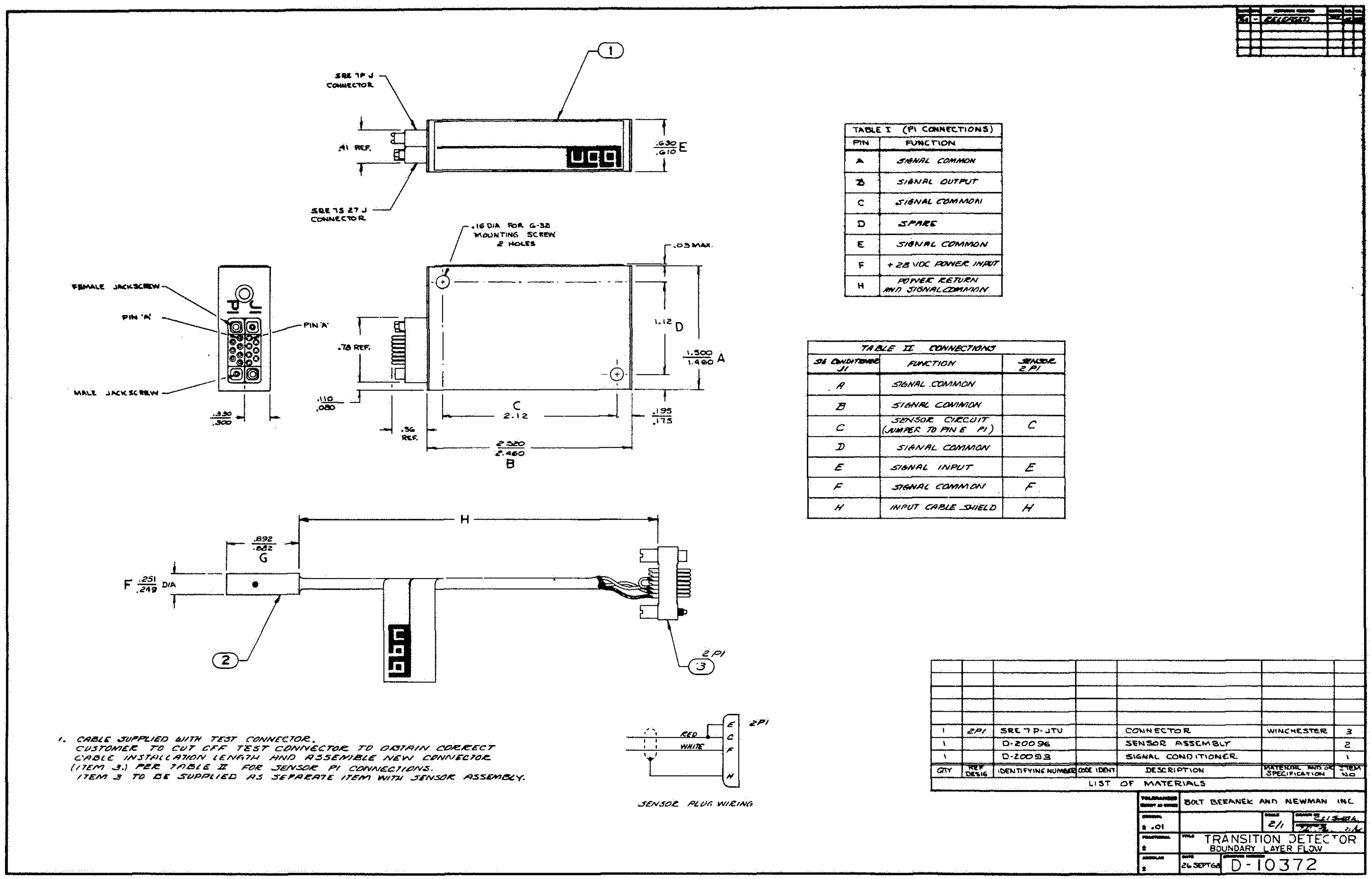
SRE 7P J CONNECTOR
.41 REF.
SRE 7S 27 J CONNECTOR
.630 / .610 E
.16 DIA FOR G-38 MOUNTING SCREW 2 HOLES
.05 MAX.
FEMALE JACKSCREW
PIN 'A'
J1
P1
PIN 'A'
MALE JACKSCREW
.330 / .300
.78 REF.
.110 / .080
.36 REF.
1.12 D
1.500 / 1.460 A
C 2.12
.195 / .175
2.520 / 2.460 B
H
.892 / .882 G
F .251 / .249 DIA
2P1
TABLE I (P1 CONNECTIONS)
PIN | FUNCTION
A | SIGNAL COMMON
B | SIGNAL OUTPUT
C | SIGNAL COMMON
D | SPARE
E | SIGNAL COMMON
F | +28 VDC POWER INPUT
H | POWER RETURN AND SIGNAL COMMON
TABLE II CONNECTIONS
SIG CONDITIONER J1 | FUNCTION | SENSOR 2P1
A | SIGNAL COMMON |
B | SIGNAL COMMON |
C | SENSOR CIRCUIT (JUMPER TO PIN E P1) | C
D | SIGNAL COMMON |
E | SIGNAL INPUT | E
F | SIGNAL COMMON | F
H | INPUT CABLE SHIELD | H
1. CABLE SUPPLIED WITH TEST CONNECTOR.
CUSTOMER TO CUT OFF TEST CONNECTOR TO OBTAIN CORRECT
CABLE INSTALLATION LENGTH AND ASSEMBLE NEW CONNECTOR
(ITEM 3.) PER TABLE II FOR SENSOR P1 CONNECTIONS.
ITEM 3 TO BE SUPPLIED AS SEPARATE ITEM WITH SENSOR ASSEMBLY.
RED
WHITE
E C F H 2P1
SENSOR PLUG WIRING
1 | 2P1 | SRE 7P-JTU | | CONNECTOR | WINCHESTER | 3
1 | | D-20096 | | SENSOR ASSEMBLY | | 2
1 | | D-20093 | | SIGNAL CONDITIONER | | 1
QTY | REF DESIG | IDENTIFYING NUMBER | CODE IDENT | DESCRIPTION | MATERIAL AND OR SPECIFICATION | ITEM NO
LIST OF MATERIALS
BOLT BERANEK AND NEWMAN INC
± .01
2/1
TRANSITION DETECTOR
BOUNDARY LAYER FLOW
26 SEPT 68
D-10372

FIG. 1

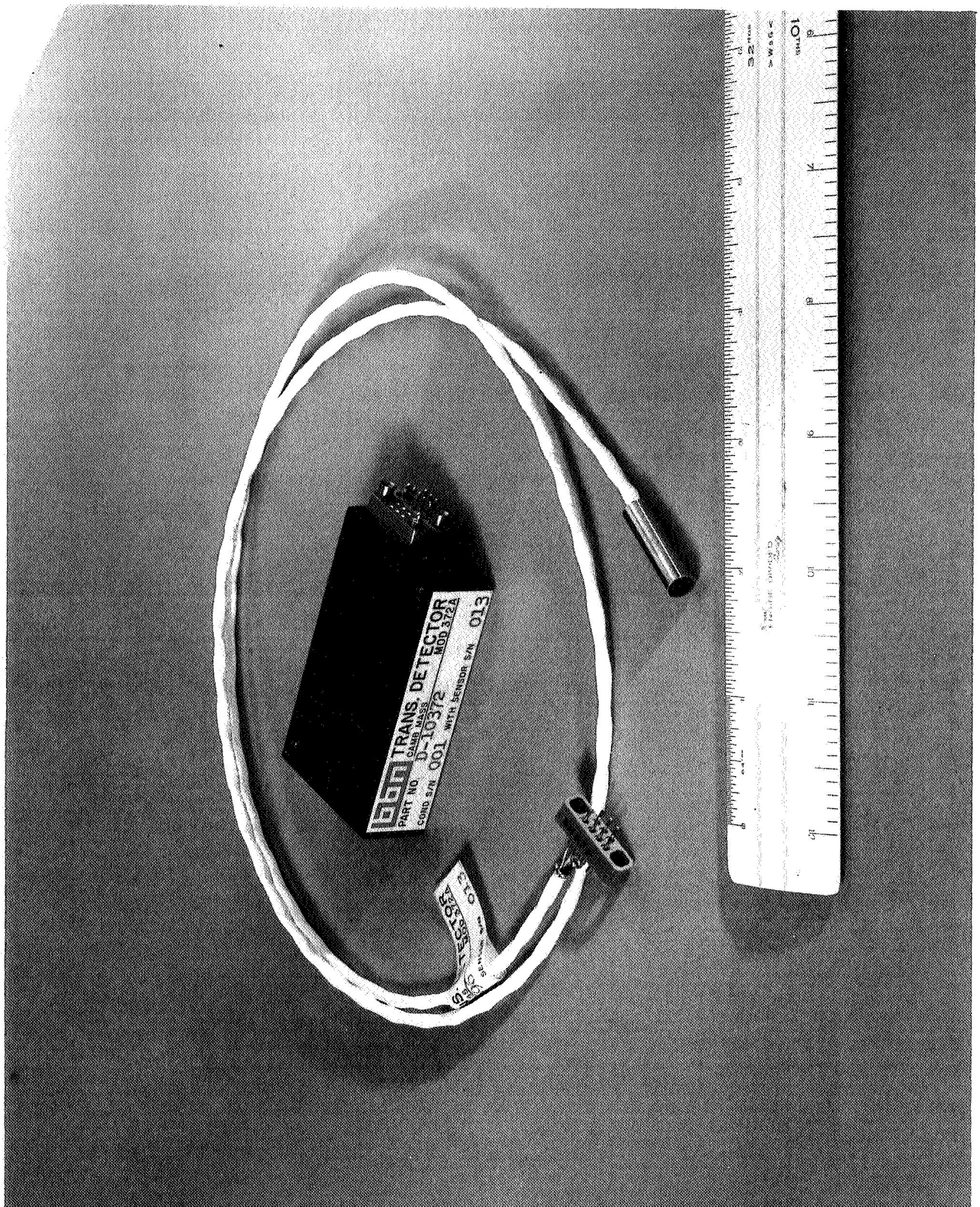

FIG.2 MODEL 372A TRANSITION DETECTOR

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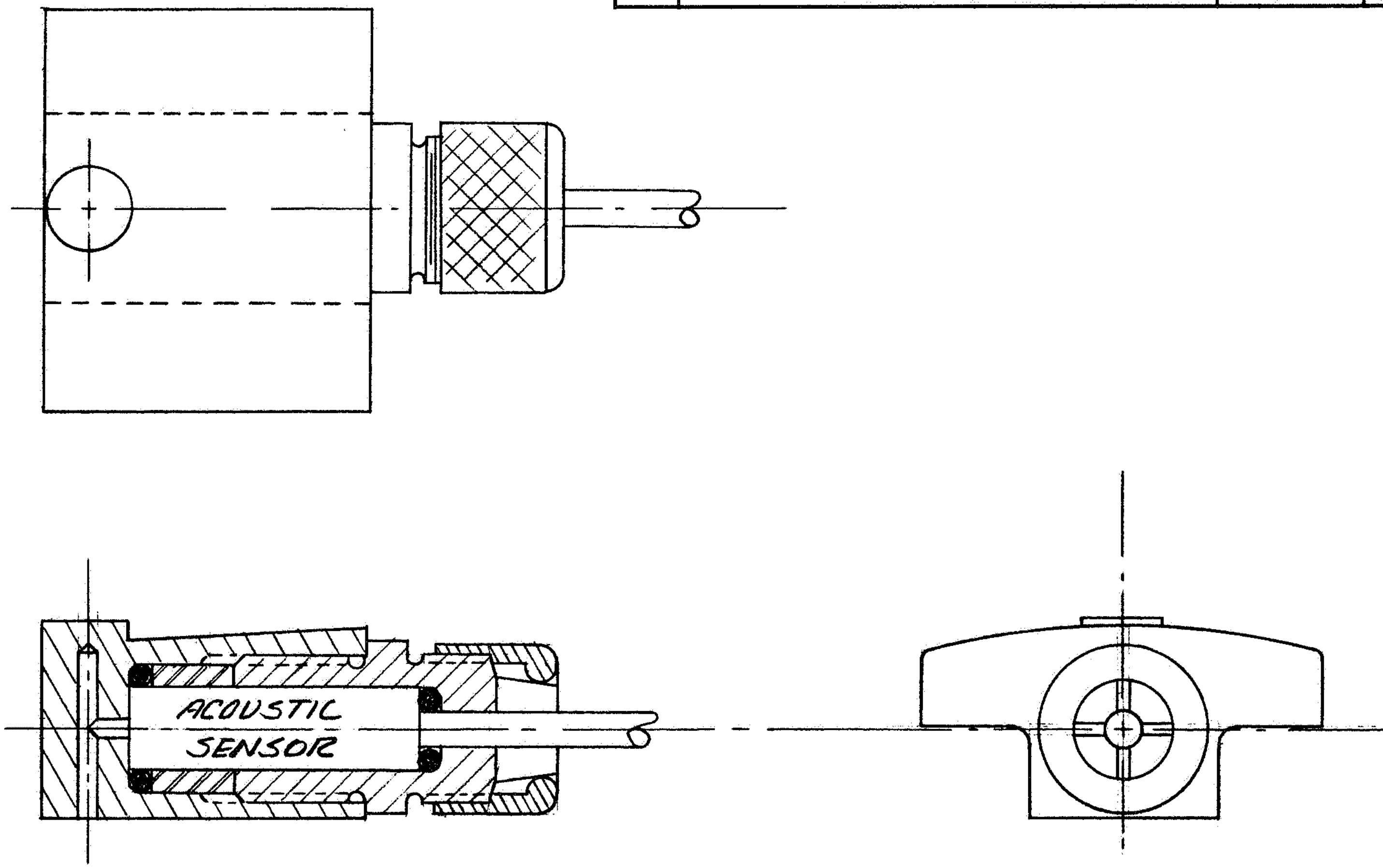

		TOLERANCES: UNLESS OTHERWISE SPECIFIED DECIMALS .XX ± .010 .XXX ± .005 FRACTIONS ± 1/64 ANGLES ± 1° REMOVE ALL SHARP EDGES.	CONTRACT NO:		**Bolt Beranek and Newman Inc.** Cambridge Massachusetts
		MATERIAL:	DRAFTSMAN H Smith	2/11/69	DRAWING TITLE ACOUSTIC SENSOR MOUNTING BLOCK
			DESIGNER H Smith	2/11/69	
			CHECKER		
			ENGINEER		
			APP'D FOR REL		SIZE A / CODE IDENT NO. / DRAWING NO. FIG.3
NEXT ASSY	USED ON	FINISH:	APP'D (CUSTOMER)		SCALE / WGT: EST CALC / SHEET / OF /
APPLICATION					

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allows the pressure in the port to equalize over the diaphragm yet is shallow enough to minimize any influence on the fundamental resonance of the port.

With a maximum heat shield thickness of 1.10 in., the anechoic chamber tests indicate a first resonance at 1.8 kHz. Under supersonic flow, the response of the coupler is expected to be as indicated in Fig. 4 for three different heat shield thicknesses. This is based upon earlier wind tunnel tests of a similar configuration at Mach 3. The response of Fig. 4c is considered conservative since the tube resonance will be at a higher frequency at higher ambient temperature, and the heat shield is expected to be generally thinner than 1.10 inches.

2.2 Sensor

The sensor (see Fig. 5) converts pressure fluctuations at the sensor diaphragm to electrical signals, through a piezoelectric ceramic bar in contact with the diaphragm. The bar shape was selected to provide high sensitivity in conjunction with the diaphragm, since the acoustic pressure is amplified approximately by the ratio of the diaphragm area to the cross-sectional area of the bar. The ratio in this design is about 50.

The electrodes of the piezoelectric bar are connected to an insulated field effect transistor (FET) located within the sensor body. The FET output impedance is about 1000 ohms, in contrast to the high (megohm level) impedance of the piezoelectric ceramic. Thus, cable vibration noise and signal losses due to cable capacitance are greatly reduced. The FET circuit has a gain of unity.

The piezoelectric bar has a capacitance of about 130 pF, and is shunted by a 1.2×10^7 ohm resistor to create an R-C filter with a 3 dB "roll-off" frequency at about 100 Hz. This filter attenuates

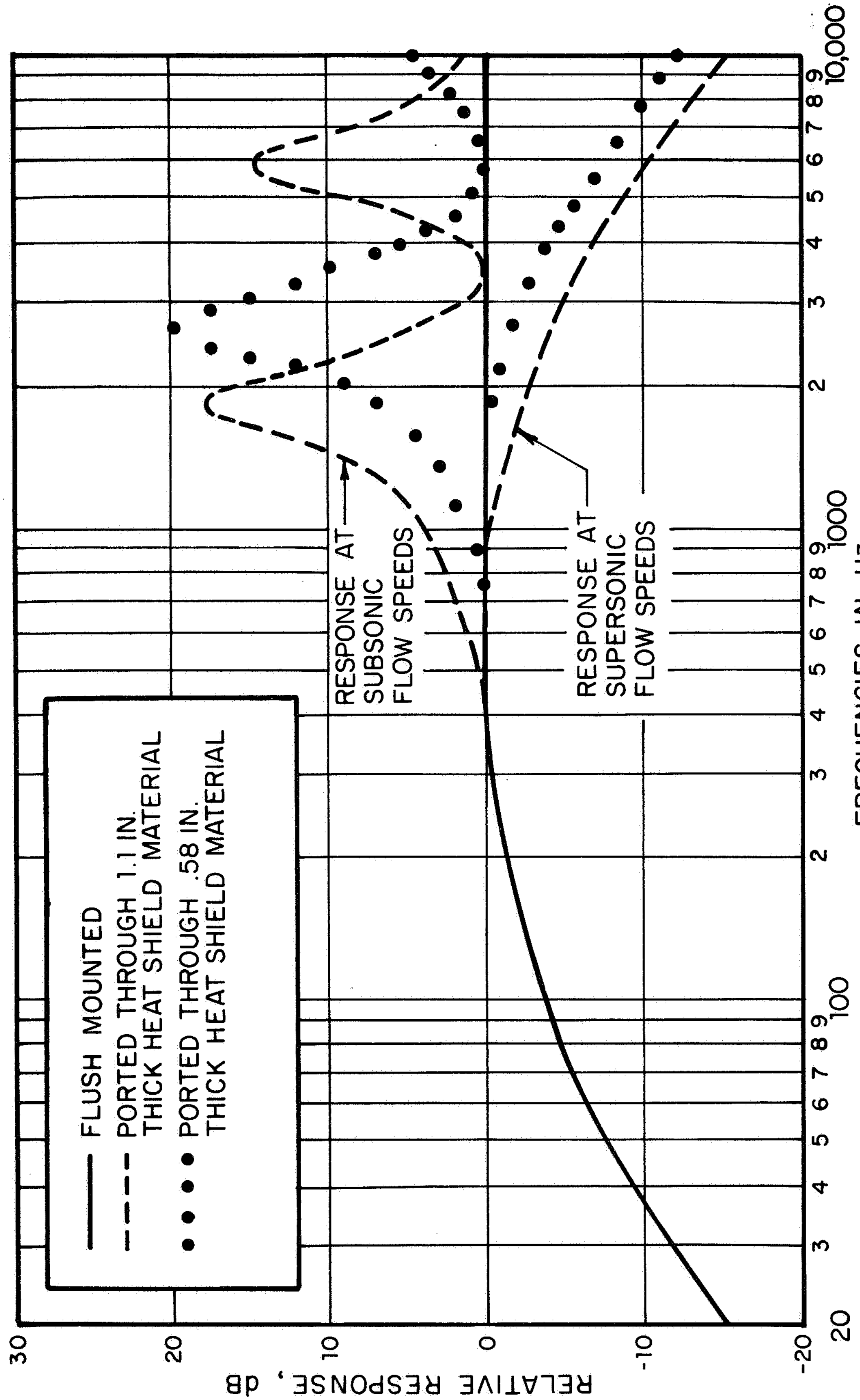
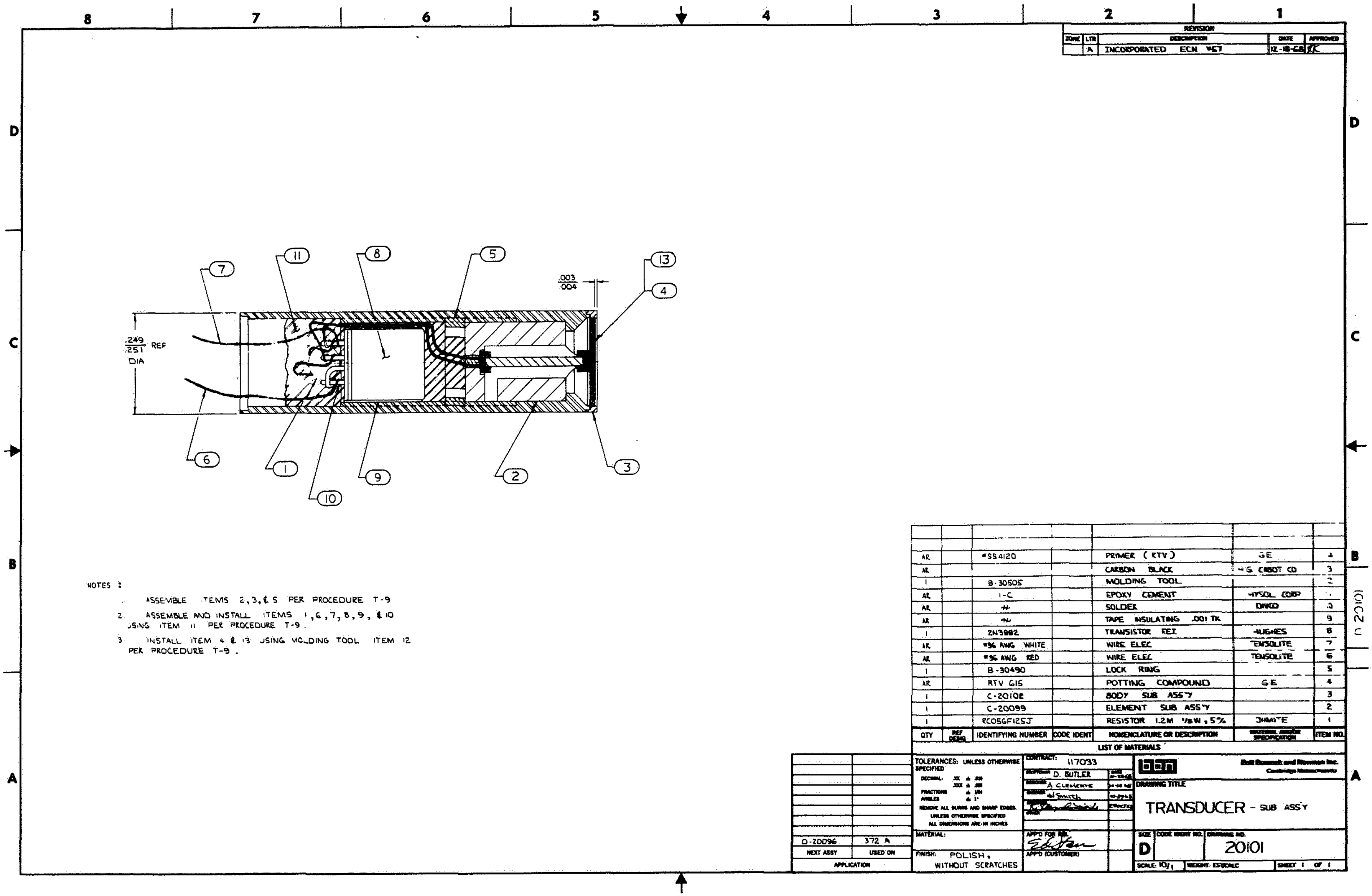


FIG. 4 FREQUENCY RESPONSE OF BBN MODEL 372A PRESSURE TRANSDUCER FOR VARIOUS INSTALLATION CONDITIONS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A INCORPORATED ECN
12-18-68
.249
.251 REF
DIA
.003
.004
NOTES :
1. ASSEMBLE ITEMS 2,3,& 5 PER PROCEDURE T-9
2. ASSEMBLE AND INSTALL ITEMS 1,6,7,8,9,& 10
USING ITEM 11 PER PROCEDURE T-9.
3. INSTALL ITEM 4 & 13 USING MOLDING TOOL ITEM 12
PER PROCEDURE T-9.
AR #SS4120 PRIMER (RTV) G.E.
AR CARBON BLACK G. CABOT CO
1 B-30505 MOLDING TOOL
AR 1-C EPOXY CEMENT HYSOL CORP
AR SOLDER
AR TAPE INSULATING .001 TK
1 2N3982 TRANSISTOR FET HUGHES 8
AR #36 AWG WHITE WIRE ELEC TENSOLITE 7
AR #36 AWG RED WIRE ELEC TENSOLITE 6
1 B-30490 LOCK RING 5
AR RTV 615 POTTING COMPOUND G.E. 4
1 C-20102 BODY SUB ASS'Y 3
1 C-20099 ELEMENT SUB ASS'Y 2
1 RC05GF125J RESISTOR 1.2M 1/8W, 5% 1
QTY
IDENTIFYING NUMBER
CODE IDENT
NOMENCLATURE OR DESCRIPTION
ITEM NO.
LIST OF MATERIALS
TOLERANCES: UNLESS OTHERWISE SPECIFIED
CONTRACT: 117033
D. BUTLER
A. CLEMENTE
D-20096
372 A
NEXT ASSY
USED ON
APPLICATION
MATERIAL:
FINISH: POLISH, WITHOUT SCRATCHES
DRAWING TITLE
TRANSDUCER - SUB ASS'Y
D
20101
SHEET 1 OF 1

FIG. 5

the potentially large signals due to low frequency vehicle oscillations that could saturate the following electronic circuits.

The sensor diaphragm (0.001 in. Type 302 stainless steel) is electron-beam welded to the sensor housing to provide a hermetic seal as well as a strong mechanical bond. A thin layer of opaque silicone rubber (RTV) is molded over the diaphragm to help reduce the heat flux reaching the ceramic and electronic components during re-entry. The RTV does not significantly affect either the pressure sensitivity or the vibration response of the sensor.

Response to vehicle vibrations are minimized by use of a highly sensitive piezoelectric ceramic material, limiting the mass of the vibrating elements in the sensor, (i.e., the diaphragm and the ceramic bar) and installing the sensor with its most sensitive (i.e., longitudinal) axis parallel to the vehicle skin.

All of the materials used in the sensor are capable of continuous exposure to temperatures of between -50°F and 300°F.

2.3 Signal Conditioner

The signal conditioner consists of three amplifiers, an active filter and a power regulator, as indicated by Fig. 6. The conditioner also contains a current source to supply power to the FET within the transducer.

As shown in the signal conditioner schematic (Fig. 7), the current source is comprised of VR1, R2, and Q1 in a common base configuration. VR1 is a voltage reference that determines the current through R2 and Q1 to the transducer.

The first amplifier consists of an integrated circuit operational amplifier and a feedback network that provides adjustable gain from 20 to 40 dB. To increase the resolution in the gain

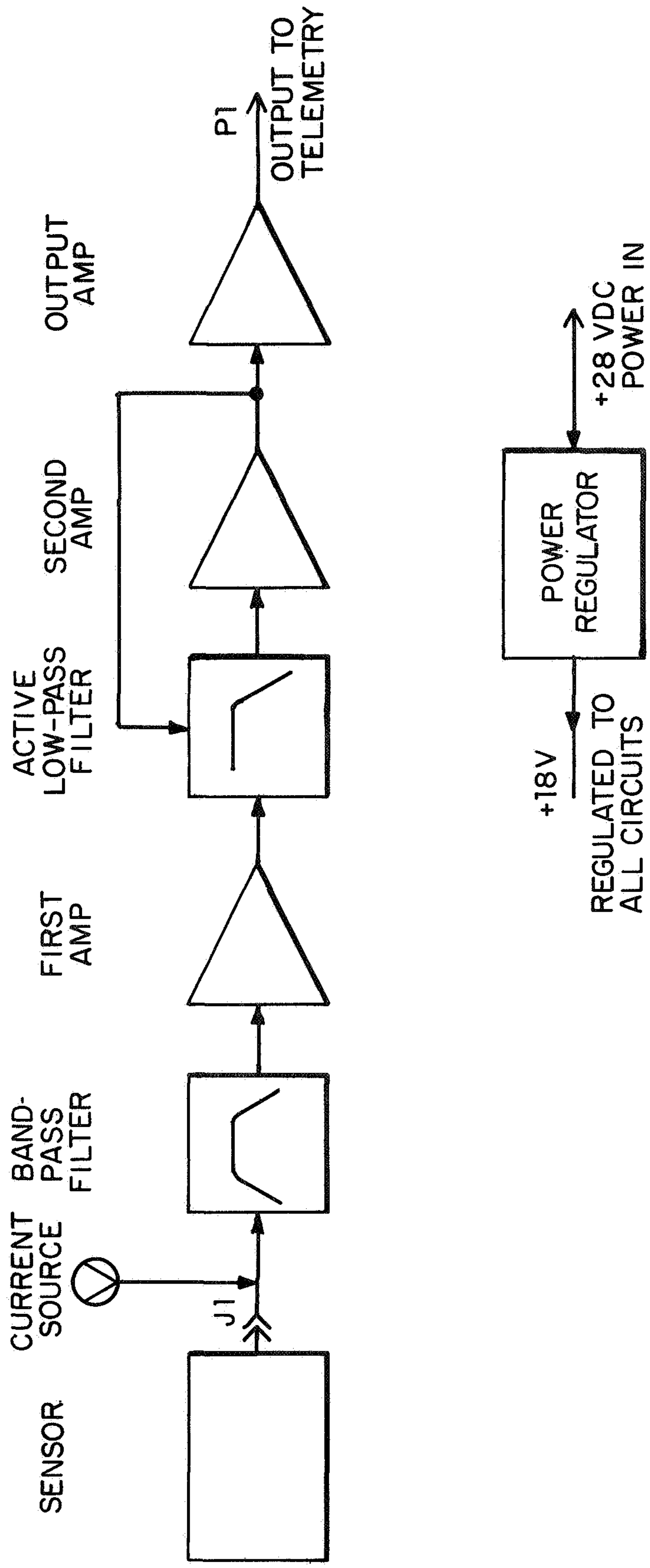


FIG.6 BLOCK DIAGRAM - MODEL 372A SIGNAL CONDITIONER

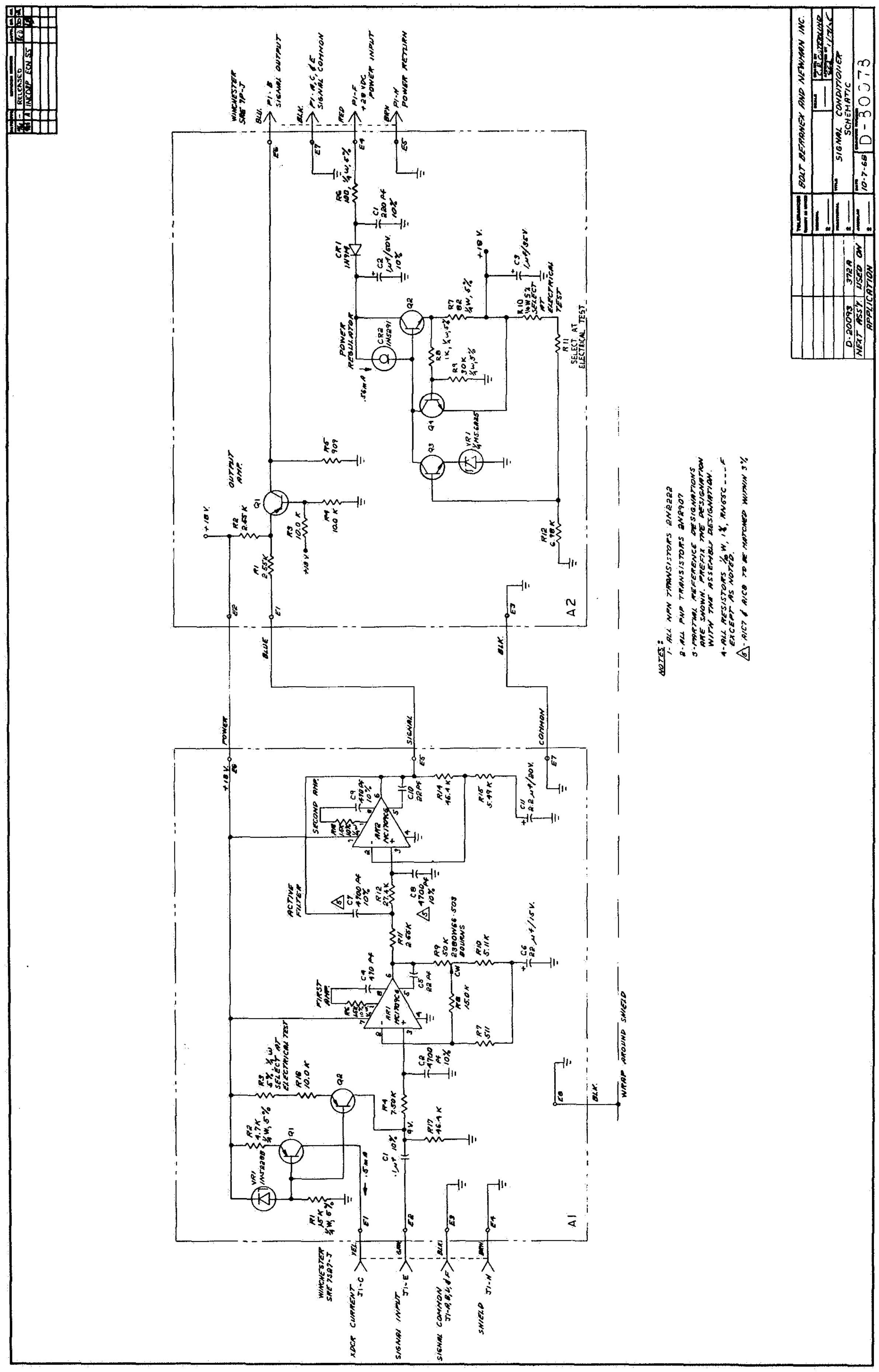

BOLT BERANEK AND NEWMAN INC.
SIGNAL CONDITIONER SCHEMATIC
D-30073
A1
A2
SIGNAL
COMMON
POWER
FIRST AMP.
SECOND AMP.
ACTIVE FILTER
OUTPUT AMP.
POWER REGULATOR
WRAP AROUND SHIELD
XDCR CURRENT
SIGNAL INPUT
SIGNAL COMMON
SHIELD
SIGNAL OUTPUT
POWER INPUT
POWER RETURN

FIG. 7

control (since subminiature pots are linear), R9 has been loaded with R7 and R8. Thus, the gain range approximates a logarithmic function. At the input to the conditioner is a high pass filter with a 34 Hz roll-off due to C1 and R17. In series with this RC is a low pass filter comprised of C2 and R4 with a 4.25 kHz roll-off. This also prevents the first amplifier from becoming overloaded at low frequencies.

To provide the output bias for the system, a common base configuration is again employed at the input to the low pass filter. VR1 is a voltage reference that determines the current through R3, R16 and Q2. This current then passes through R17, which determines the bias voltage. A final roll-off comprised of C6 and the feedback resistor network provide for unity gain at DC.

Following the first amplifier is a low pass filter comprised of C8 and R12 with a 4.06 kHz roll-off. A second roll-off, C7 and the resistive feedback network provide some positive feedback within the second amplifier. This provides for the realization of complex poles. Along with C2 and R4 these RC filters combine to form an active filter about the second amplifier. As in the first amplifier, the feedback network and C11 provide for unity gain at DC. The gain of the second amplifier is 20 dB.

Output voltage swing is limited by the second amplifier and the output amplifier. Protection from an output short circuit is afforded by R5.

The power regulator takes 28 VDC input and provides filtered, regulated 18 VDC for operation of the circuits within the conditioner. This regulator is short-circuit-proof due to CR1; current and voltage regulation are provided within. Q4, which controls the pass transistor Q1, senses the current through R7, thus providing current regulation. Q3 and VRI provide a voltage reference through which the voltage is controlled. The input voltage may be changed ±10% with no change in the regulated 18 volts.

3. PERFORMANCE REQUIREMENTS

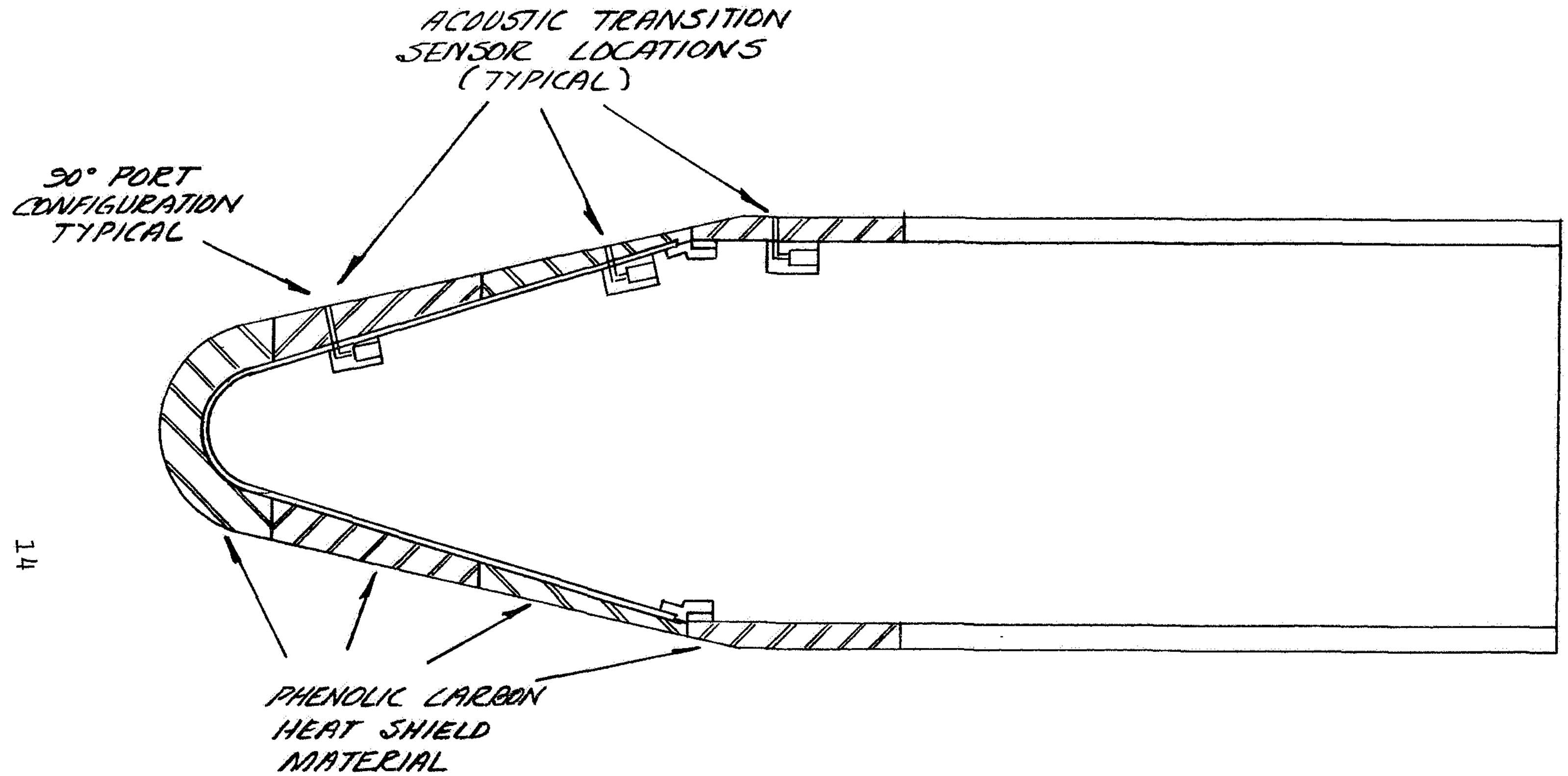
The acoustic transition detection system described in this report is designed to measure the turbulent pressure in the boundary layer as turbulent flow develops on the Pacemaker phenolic carbon vehicle. Three sensor locations, as indicated in Fig. 8, have been selected to afford transition wavefront mapping.

The first task is to estimate the turbulent pressure levels at the points of interest. Next, the system's electrical performance characteristics required for this measurement are established. Finally, non-operating performance requirements for this mission are given.

3.1 Sound Level Prediction

The acoustic environment for the Pacemaker phenolic carbon re-entry vehicle has been estimated for several points of the trajectory, based on data provided by NASA-LRC. This data is summarized in Table 1 and was used as the input to a procedure developed by Bies (Ref. 2) for determination of the fluctuating pressure spectrum for subsonic flow. The resulting spectra are extrapolated to the supersonic case by applying the experimental corrections discussed in Ref. 3. The characteristics of the supersonic spectra over the frequency band selected for the measurement have been considered in conjunction with telemetry system characteristics to arrive at the optimum specifications for the transition detector system.

The boundary layer data provided by NASA have been compared to a transition criterion reported in Ref. 4. The calculated local Reynolds Number ($R_{e_{\delta*}}$) and Mach Number data cluster in a region of extreme scatter in the previously obtained flight data (Fig. 9). Consequently, the state of the flow (i.e., laminar or turbulent) cannot be conclusively established and, for the purposes of subsequent analysis, will be considered transitional.



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TOLERANCES: UNLESS OTHERWISE SPECIFIED
DECIMALS .XX ± .010
.XXX ± .005
FRACTIONS ± 1/64
ANGLES ± 1°
REMOVE ALL SHARP EDGES.

MATERIAL:

FINISH:

NEXT ASSY | USED ON

APPLICATION

CONTRACT NO:

DRAFTSMAN H Smith 2/11/69

DESIGNER H Smith 2/11/69

CHECKER

ENGINEER

APP'D FOR REL

APP'D (CUSTOMER)

bbn **Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

DRAWING TITLE
SENSOR LOCATIONS
MOD. 372A

SIZE A | CODE IDENT NO. | DRAWING NO. FIG.8

SCALE | WGT: EST CALC | SHEET 1 OF 1

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TABLE I

FREE STREAM PARAMETERS						BOUNDARY LAYER PARAMETERS						
Traj Time (sec)	M_∞	P_{stag} (atmos)	V_∞ (ft/sec)	Altitude (ft)	Remarks	Vehicle Station (ft)	δ^*_{turb} (in)	q_δ (lb/ft)	V_δ (ft/sec)	Re_δ	M_δ	FPL_T (dB)
60.2	2.8	0.86	2708	53,982	3rd stage burn	0.456	0.0403	523	2597	2309	2.52	116
						1.020	0.0802	487	2646	2932	2.63	119
						1.440	0.1261	343	2802	5726	3.05	118
64.9	7.0	5.25	6808	55,500	4th stage burn	0.456	0.0406	2865	5169	1710	2.46	128
						1.020	0.0840	2439	5369	1673	2.66	130
						1.440	0.1471	1314	5870	2583	3.30	126
66.8	10.5	12.27	10208	56,726	4th stage termination	0.456	0.0396	5892	7119	1211	2.37	133
						1.020	0.0836	4871	7455	1373	2.57	134
						1.440	0.1488	2544	8283	2169	3.18	131
74.7	7.9	5.5	7678	60,000	coast	0.456	0.0409	2923	5715	1531	2.45	127
						1.020	0.0859	2470	5946	1767	2.65	129
						1.440	0.1550	1315	6517	2762	3.30	126

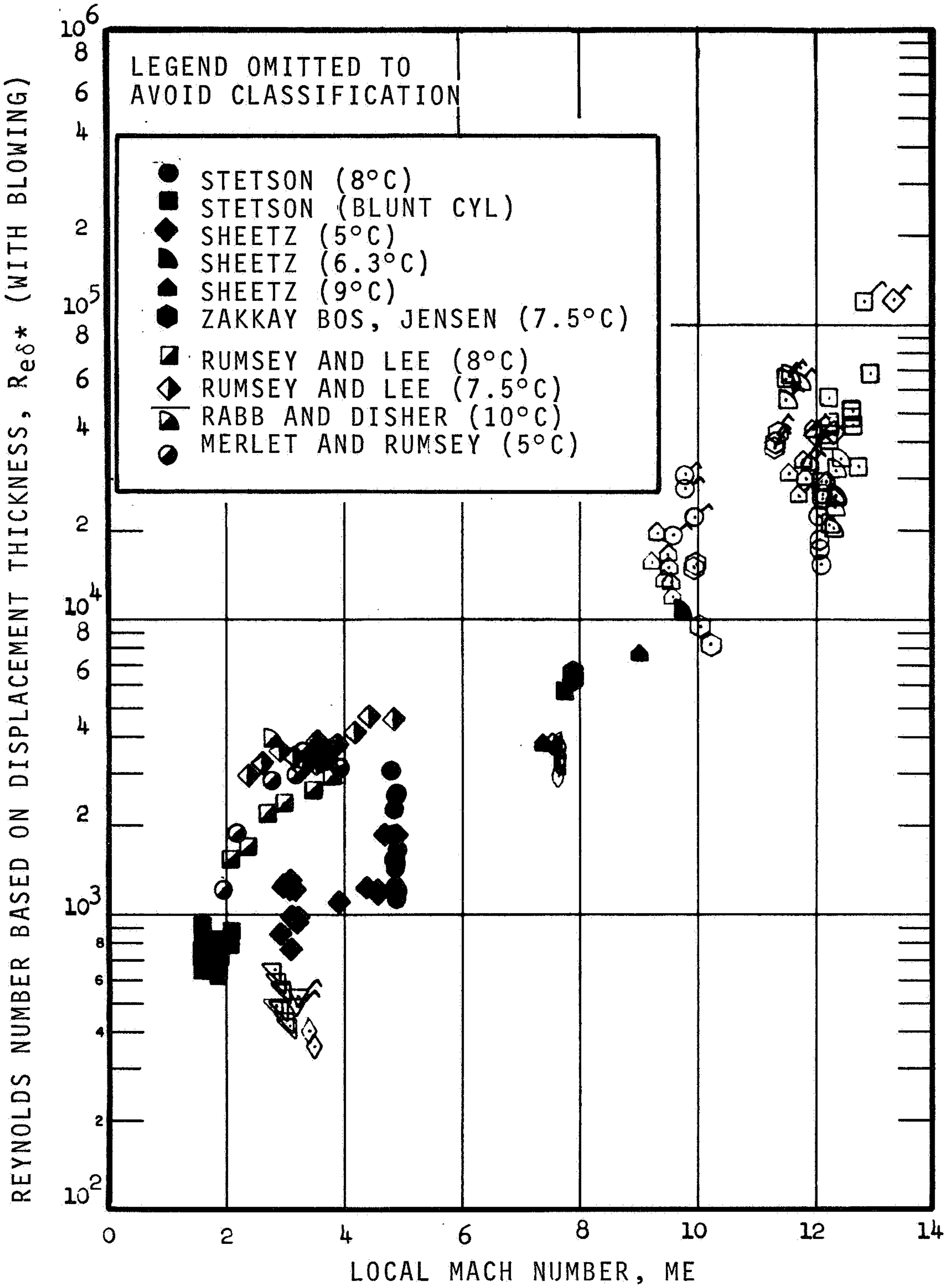


FIG.9 TRANSITION CORRELATIONS

The boundary layer parameters contained in Table 1 have been used as the input to an empirical prediction scheme based on a large number of actual flight and experimental wind tunnel data. The general shape of the third octave band fluctuating pressure spectrum vs the center frequency of each 1/3-octave band is provided in Fig. 10. The spectrum rises at a rate of 3 dB/octave to a peak level and drops at a rate of 9 dB/octave thereafter. The location of the peak frequency is obtained from

$$f_{peak} = \frac{1}{6} \quad U/_{\delta *} \ . \tag{1}$$

The overall fluctuating pressure level can be calculated from

$$FPL_{OA} = 20 \log q + 84 \text{ dB}, \tag{2}$$

with q in lb/ft .

The actual peak of the spectrum is then established by fairing a smooth curve as illustrated (Fig. 10) with a maximum value 6 dB down from the point calculated by the above equations.

This estimation procedure, valid for the subsonic case, cannot readily be applied to the case of hypersonic flow speeds associated with re-entry. It is expected that the levels under hypersonic flow will be lower due to compressibility effects. The questions of how much the levels drop and whether the general shape of the spectrum changes were resolved by a test of a conical model in a well-understood supersonic wind tunnel (Ref. 3). It was found that the extrapolated subsonic estimates are high by about 15 dB in the frequency range of interest.

Supersonic wind tunnel tests of flow transition on a flat test plate in a Mach 3 flow (Ref. 4) revealed that, during the trans-
flow regime, the fluctuating pressure levels increase quite

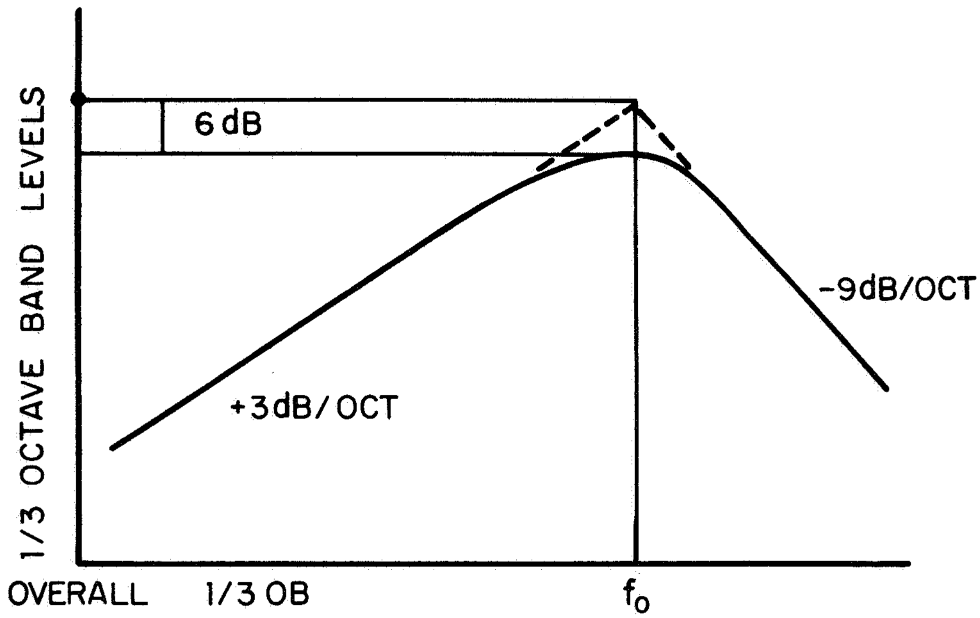


FIG.10 SPECTRUM SHAPE

rapidly and then decrease after turbulent flow is established. The experimental data show that the levels drop by approximately 10 dB. We would, therefore, estimate that the FPL-spectrum under transitional flow lies approximately 5 dB under the subsonic estimates.

In summary, the transitional spectra for the Pacemaker flight environment have been obtained as follows:

1. perform the subsonic estimation procedure, using the relevant aerodynamic parameters (δ^*, V and q) for the flight conditions;
2. lower the levels by 15 dB, in order to obtain the FPL-spectrum for the turbulent boundary layer on the surface of a cone; and
3. increase the turbulent levels by 10 dB to obtain the estimate for the transitional regime.

The *rms* fluctuating pressure levels for the 0 to 4000 Hz band at the various trajectory times and vehicle stations are shown in Table 2.

TABLE 2

Vehicle Station (feet)	TRAJECTORY TIME (Sec.)			
	60.2	62.9	66.8	74.7
0.456	116 dB	128 dB	133 dB	127 dB
1.02	119 dB	130 dB	134 dB	129 dB
1.44	118 dB	126 dB	131 dB	126 dB

3.2 System Performance

Once the anticipated turbulent pressure levels are known, the performance specifications for the system can be stated:

1. Full Scale SPL
   Nominal full scale SPL is 125 dB SPL equal 1 V rms output. This range is to be adjustable between 120 and 135 dB SPL with a potentiometer.

2. Frequency Response
   Excluding transducer port, within 3 dB (±1.5 dB) from 120 to 4000 Hz.

3. Output Noise Level
   More than 30 dB below the minimum full scale SPL over the full bandwidth.

4. Electrical Power
   Less than 20 ma from 28 V ±10%.

5. Output
   - Biased at +2.5 V ±0.2 V.
   - Clipping levels: +5 to +5.75 V and -0.5 to +0.1V over full temperature range; +5.25 to +5.50°V at 25 C.
   - Impedance: less than 1000 ohms, DC to 100 kHz.

6. Overload Recovery
   Normal AC operation restored in 10 msec after an overload equivalent to 155 dB SPL.

7. Power Interaction
   - Less than 0.1 dB change in sensitivity for a ±10% change in 28 v dc input power.
   - AC signals superimposed on the 28 Volt line at 3 V rms from 30 to 1500 Hz and decreasing by 4 dB/octave to 100 kHz will not yield output signals greater than -30 dBV rms.

8. RFI

System will conform to MIL Standards 461, 462 and 463.

3.3 Environmental Requirements

Environmental requirements are stipulated in the contract for these systems. These are tabulated below for both Operating and Non-Operating conditions

3.3.1 Operating environments

TEMPERATURE:

- from +50 to +120°F, less than ±0.3 dB change in sensitivity.
- +20 to +160°F, less than ±1.0 dB change in sensitivity.
- output bias and clipping, ±0.2 V from +20 to +160°F.
- all other parameters of Sec. 1 should be met at the temperature extremes.

VIBRATION:

Transducer and Cable

Less than 125 dB/g equivalent for random excitation, 100 to 4000 Hz in normal axis; less than 110 dB/g in other axes.

Signal Conditioner

Less than 1 mV rms/g output in 100 to 4000 Hz band, all axes.

ALTITUDE:

At 100,000 ft, sensitivity at 250 Hz within ±1 dB of original sensitivity.

3.3.2 Non-operating environments

The system shall operate without degradation after exposure to the following conditions. The system will not be operating during these conditions, but performance data will be taken after the exposure.

TEMPERATURE:

Transducer: +20 to +200°F, in 20° steps, 30 min at each step.

Signal Conditioner: +20 to +160°F, in 20° steps, 30 min at each step.

VIBRATION:

Sine sweep: 3 axis, 20-2000 Hz at 2 oct/min at ±25 g peak.

Random: 3 axis, 20-2000 Hz, 60 sec each axis at 12 g rms.

ACCELERATION:

Longitudinal (vehicle): ±160 g's for 30 sec.

Lateral (vehicle): ±25 g's for 30 sec.

SHOCK:

Longitudinal: ±300 g sawtooth for 10 msec.

Lateral: ±80 g sawtooth for 10 msec.

ALTITUDE:

Remain at 50,000 and 100,000 ft for 30 min each.

Note: No specific tests on the effect of 4 millicuries of radiation from the tantalum-182 radioisotope were conducted with our transducer. However, the above type of radiation source is encompassed in tests conducted by AVCO Missile Systems Division personnel and has been found to be not harmful to semiconductor components similar to those used in our transducer.

4. TEST PROGRAM

Tests were conducted of specific characteristics of the system as normal quality control procedures and for Pacemaker Vehicle flight qualifications.

4.1 Engineering Performance Tests

Particular tests were performed to indicate that the equipment would meet the general requirements. These are listed below:

4.1.1 Sensor

Frequency Response (Fig. 11)
Vibration Response (Fig. 12)
Sensitivity Relative to Temperature (Fig. 13)

4.1.2 Conditioner

Frequency Response (Fig. 14)
Electrical Noise Floor (Fig. 15)
Gain Relative to Temperature (Fig. 16)
Gain Adjust (Fig. 17)
Regulation (Fig. 18)

4.2 Quality Control Testing

During fabrication, the equipment supplied under the contract was controlled and tested to procedures meeting the requirements of MIL-Q-9858A, MIL-C-45662A, MAS Quality Publication, NPC-200-3 and NHB-5300-4.

The flow of materials through quality control procedures is illustrated in Fig. 19. From initial procurement to shipment of

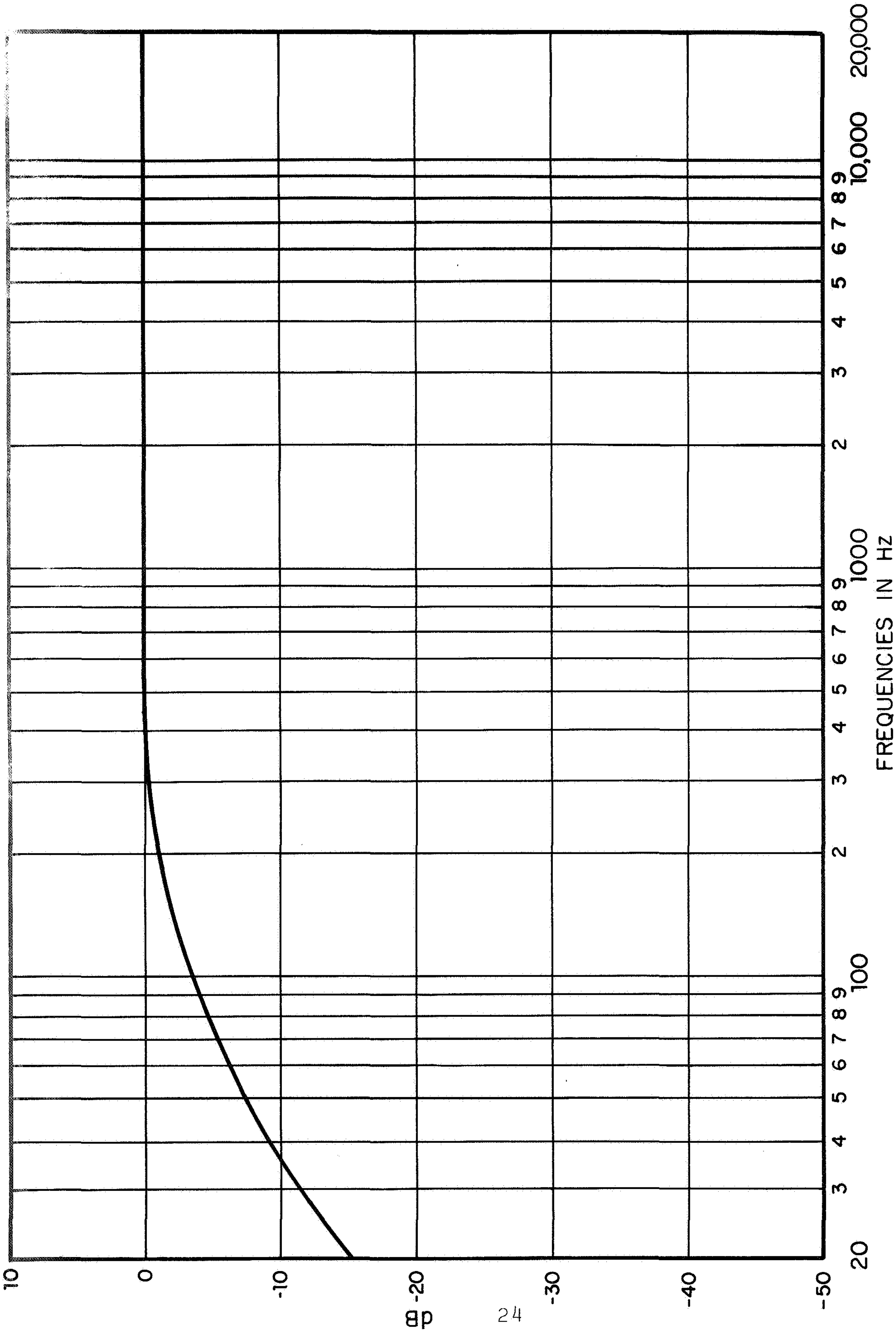


FIG.11 SENSOR FREQUENCY RESPONSE

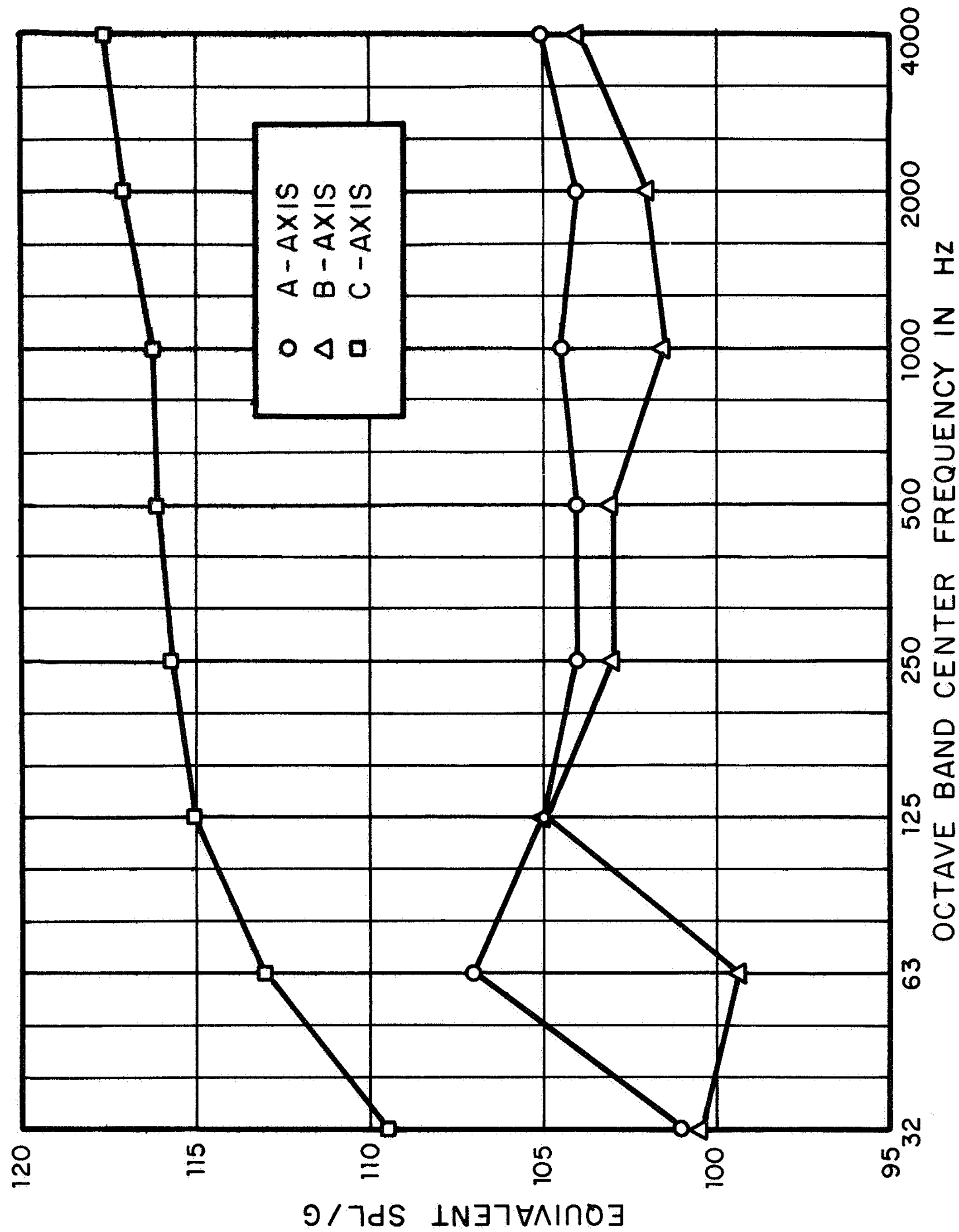


FIG.12 VIBRATION SENSITIVITY, SENSOR

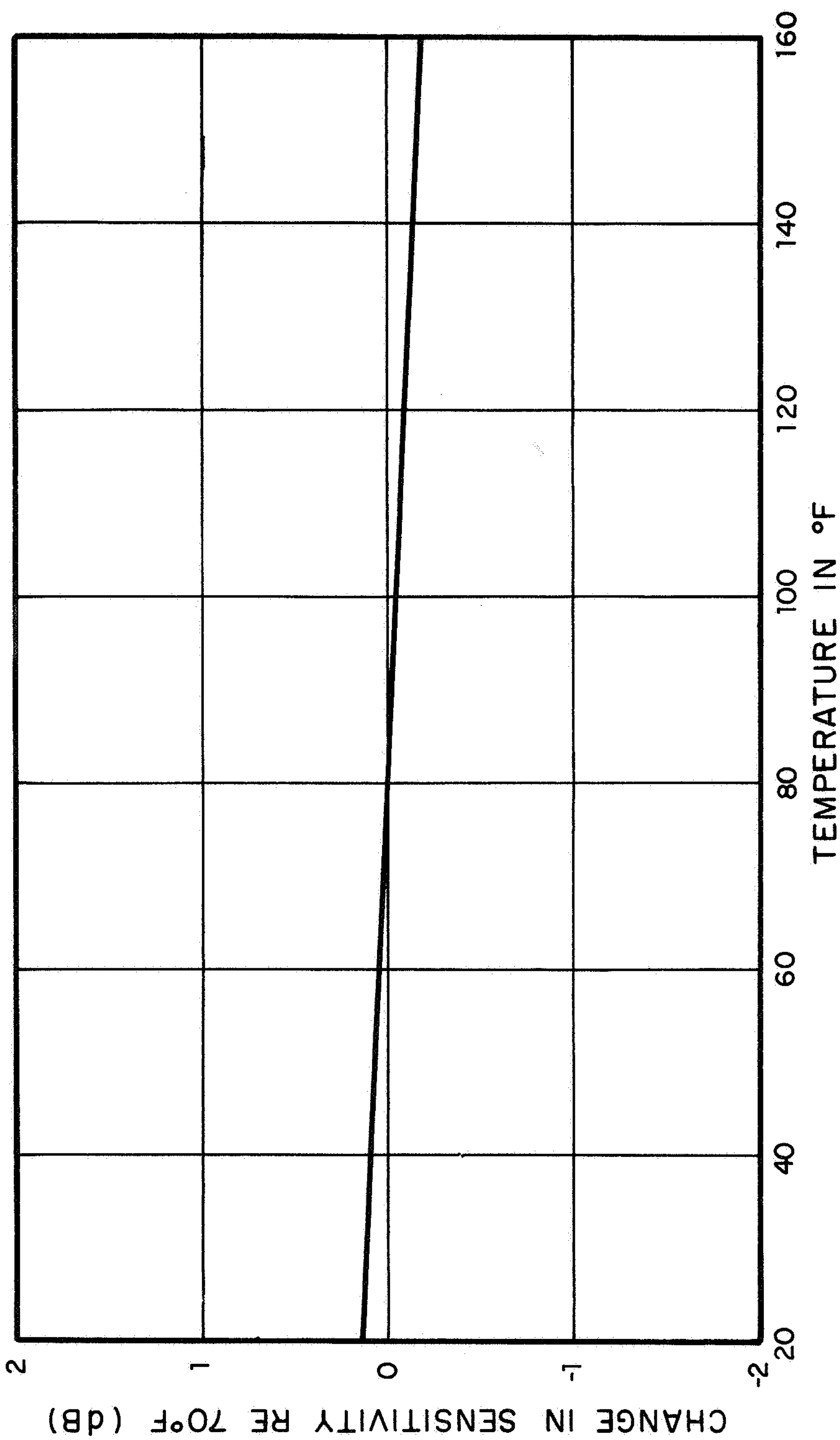


FIG.13 1kHz SENSITIVITY VS. TEMPERATURE, SENSOR

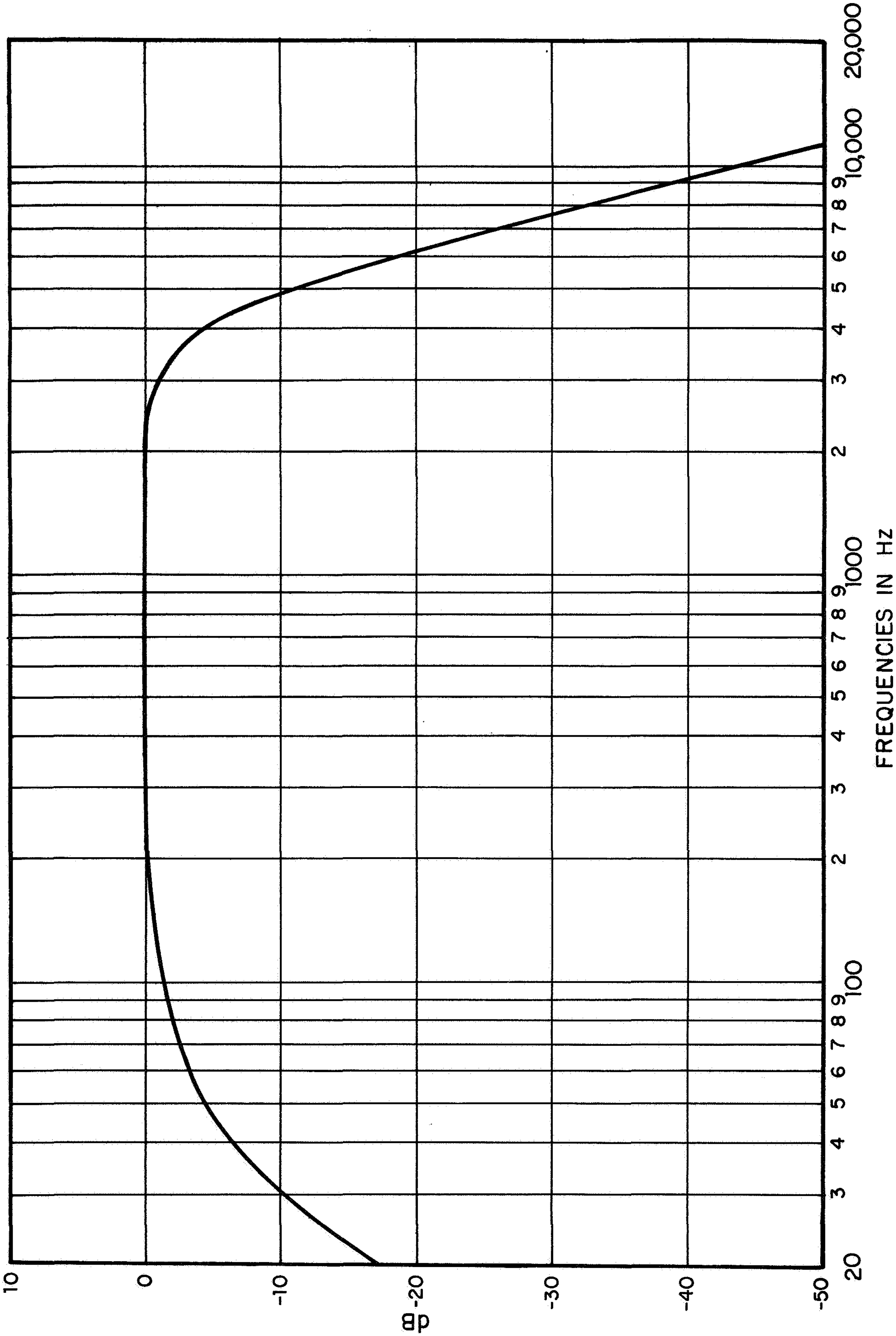


FIG.14 SIGNAL CONDITIONER FREQUENCY RESPONSE

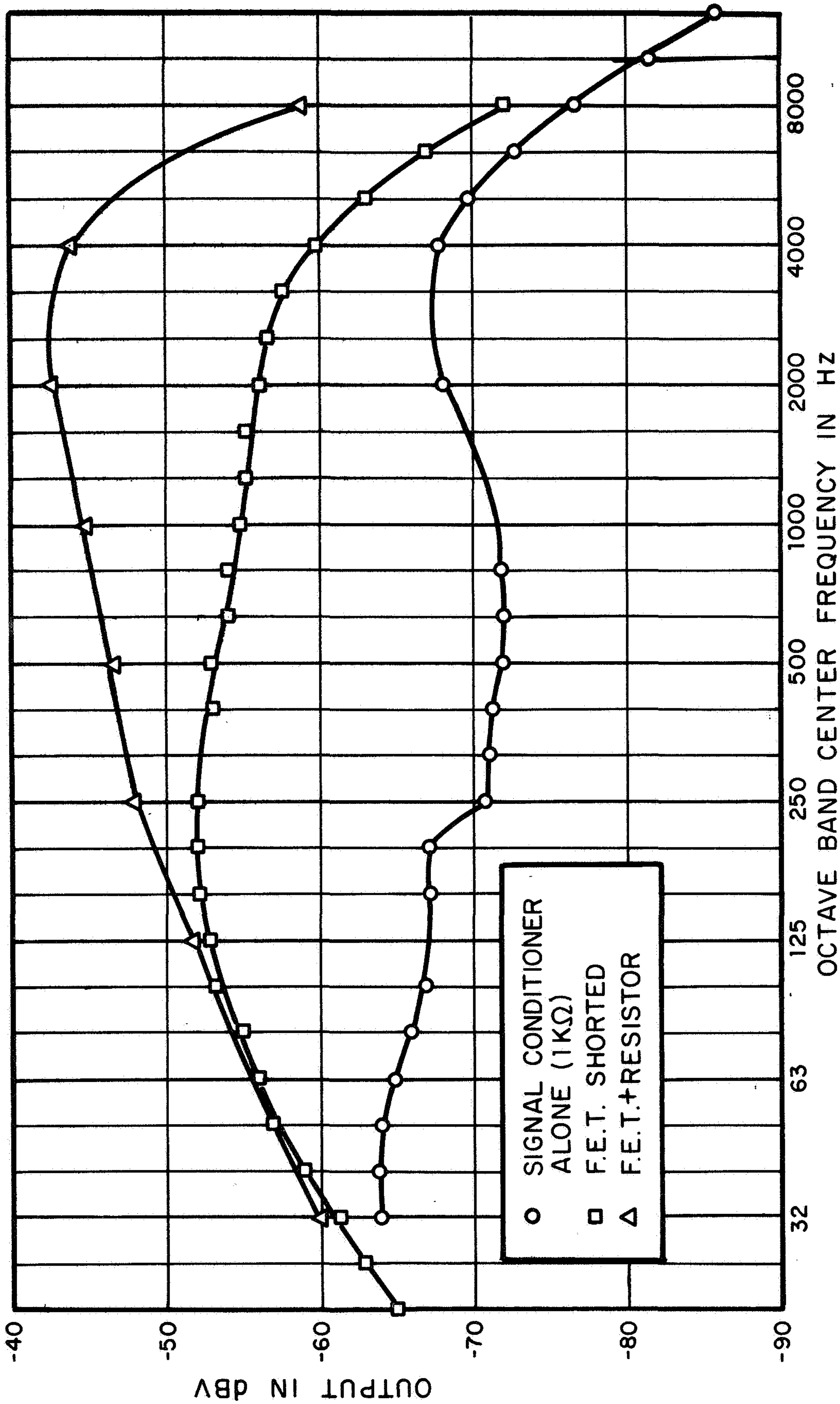


FIG.15 ELECTRICAL NOISE FLOOR

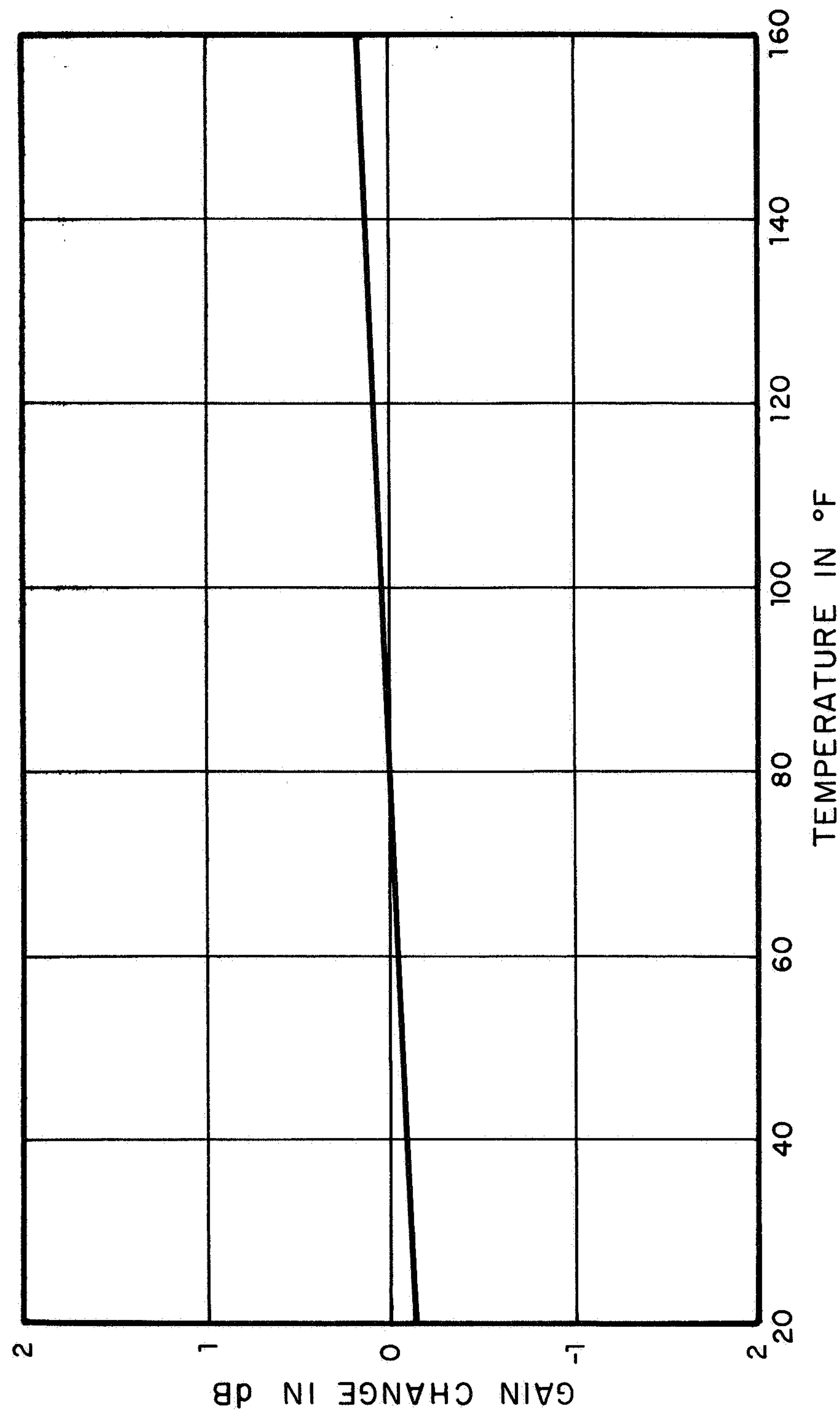


FIG.16 1kHz GAIN VS. TEMPERATURE, SIGNAL CONDITIONER

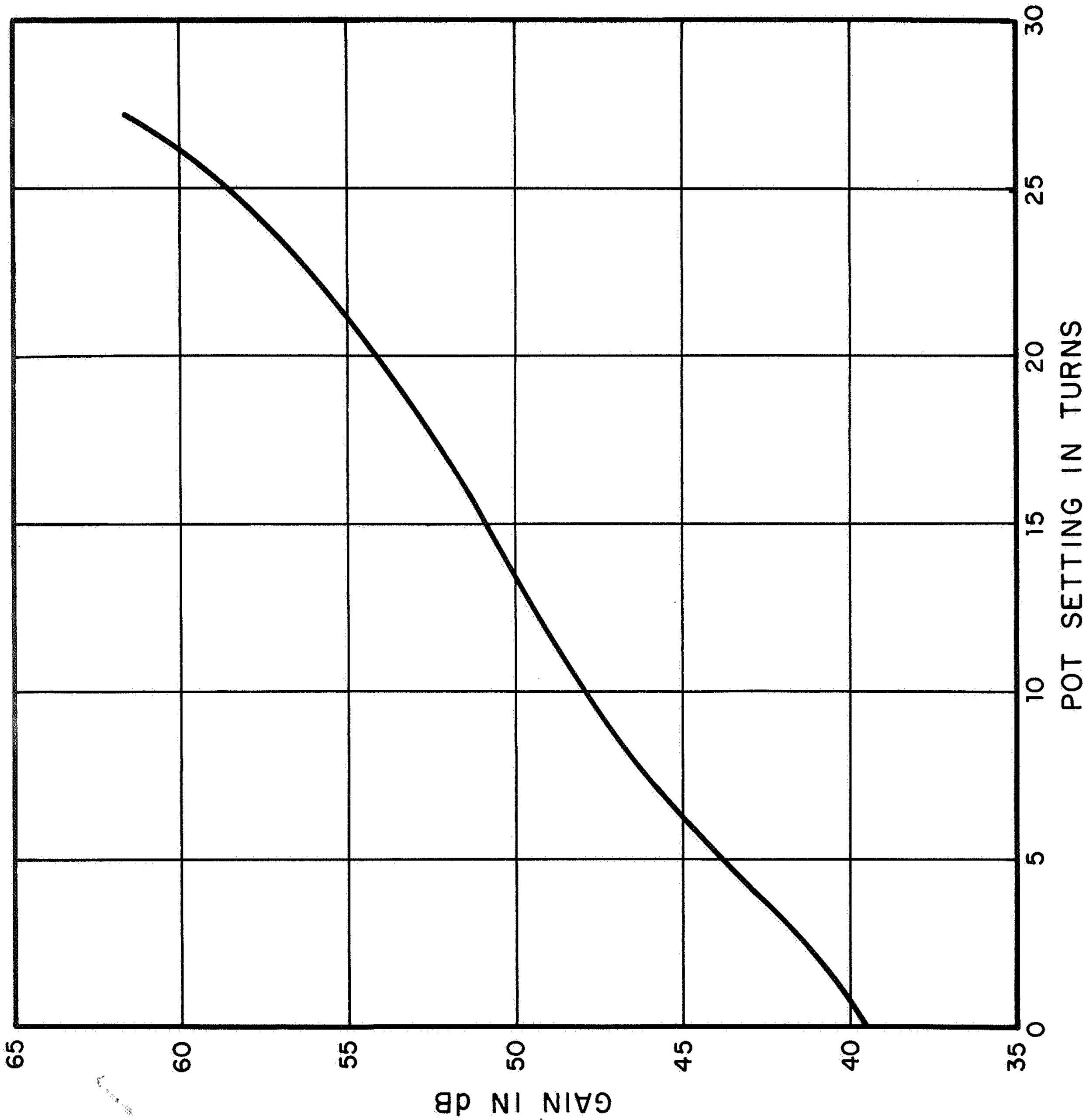


FIG.17 GAIN VS. POT SETTING

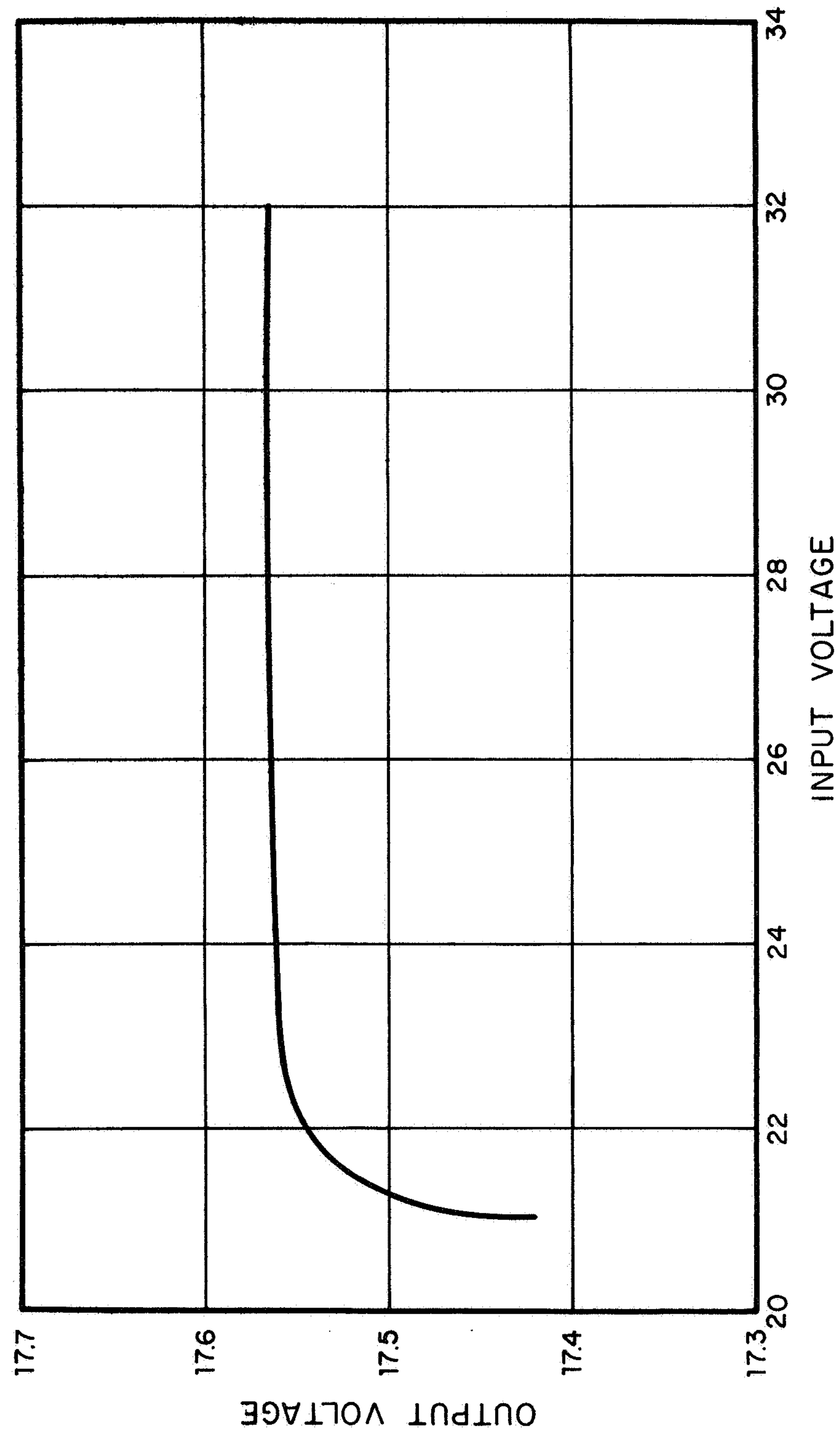


FIG.18 POWER SUPPLY REGULATION

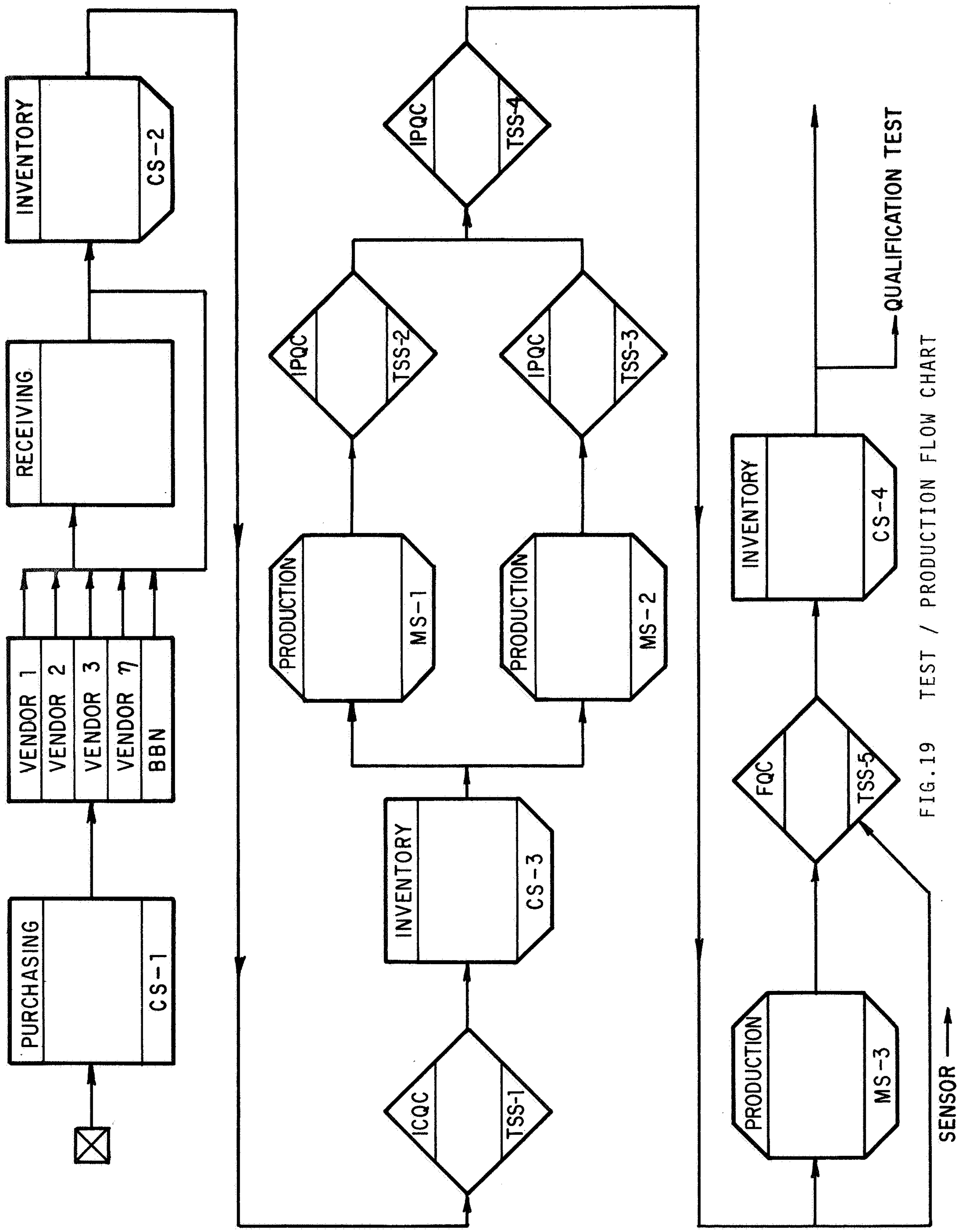


FIG.19 TEST / PRODUCTION FLOW CHART

the finished product, each item is subjected to these procedures. Specific test procedures are supplied in Appendix A. Specific test results for each system are itemized in Appendix B. A brief itemization of the control points is given.

KEY

CS-1	Control Station Function: Component procurement from outside sources and BBN. Documents: Requisition/purchase order procurement status chart.
Receiving	Function: Receive component from outside sources and verify requisition/purchase order information. Documents: Packing slip.
CS-2	Control Station Function: Inventory, Kit. Documents: Inventory slip.
TSS-1	Test Station Function: Incoming inspection and test of components. Documents: Inventory slip, test procedure.
CS-3	Control Station Function: Prepared components for routing to manufacturing station. Documents: Work instruction check list.
MS-1	Manufacturing Station Function: Assemble printed circuit boards and attach connector. Documents: Work instruction (PWB A1); Work instruction (PWB A2); Work instruction (connection); Check List for Above.

MS-2	Manufacturing Station Function: Sensor Assembly. Documents: Work instruction check list.
TSS-2	Test Station Function: In-process signal conditioner test. Documents: Test Procedure.
TSS-3	Test Station Function: In-process sensor test. Documents: Test procedure.
TSS-4	Test Station Function: In-process system test. Documents: Test procedure.
MS-3	Manufacturing Station Function: Final Assembly of signal conditioner. Documents: Work instruction; Check list.
TSS-5	Test Station Function: Final system test. Documents: Work instruction equipment log sheet.
CS-4	Control Station Function: Preparation for delivery. Documents: Final test results; Equipment log sheet; Frequency response sensor; Signal conditioner.

4.3 Qualification Testing

4.3.1 General

One acoustic transition detection system, Type D10372, was selected at random from the first four systems fabricated. The system consisted of sensor SN-004 and signal conditioner SN-010.

4.3.2 Shock, vibration, and acceleration

The selected system was exposed to the environment specified for the Pacemaker Materials Technology Experiment (Table 3) while operating. All conditions of the qualification test except temperature and altitude were performed by Associated Testing Laboratories Inc. (ATL) at Burlington, Mass. from 25 to 27 November 1968. These tests were witnessed by K. Kleinschmidt from BBN. The ATL report covering these tests is included as Appendix C.

Comments on the Tests Performed at ATL:

a. A 27-volt battery supplied power to the system during all environmental exposure tests.

b. During random and sinusoidal vibration testing, the output signal was observed on an oscilloscope.

c. Whenever practical, before or after each test sequence, the sensitivity of the system to a 250 Hz sine wave at 124 dB SPL was determined. A calibrated Bruel and Kjaer pistonphone type 4220 was used. The amplitude, frequency, and waveform were observed on an oscilloscope. At no time were changes in the output signal greater than the expected accuracy of the measurement. The noise level of the system was observed and, while it at no time showed any marked changes, the variable acoustic background noise in the test area was occasionally high enough to be observed above the system noise (equivalent to about 85 dB SPL).

d. The longitudinal and transverse axes referred to in the ATL report are the transducer axes, since the longitudinal axis is parallel to the transducer's

TABLE 3

PACEMAKER MATERIALS TECHNOLOGY EXPERIMENT
OPERATING ENVIRONMENTAL TEST CONDITIONS

ENVIRONMENT	QUALIFICATION UNIT (1)	
	SPECIFICATIONS	TESTS
Sine Sweep Vibration	±25g's 0.8 in DA	3 axes, plus and minus 20 - 2000 Hz 2 oct/min
Random Vibration	12g rms	3 axes, plus and minus 20 - 2000 Hz 60 seconds
Acceleration	±160g A_L ±25g A_T and A_N	3 axes, plus and minus 30 seconds
Shock	±300g A_L ±80g A_T and A_N	3 axes, plus and minus 10 milliseconds Sawtooth pulse shape
Temperature Excluding Transducer	20^{o}F to 160^{o}F	20^{o}F steps, 30 minutes at each step
Temperature (Transducer)	20^{o}F to 200^{o}F	20^{o}F steps, 30 minutes at each step
Altitude	Vacuum equivalent to altitude of $.5 \times 10^5$ ft and 10^5 ft	30 minutes at each equivalent pressure

axis of symmetry. The signal conditioner and transducer always maintained the relationship shown in Fig. 1 of ATL's report.

4.3.3 Temperature and altitude

The temperature and altitude conditions were performed at BBN facilities on 4 and 5 December 1968. These tests are described below:

a. Temperature exposure was obtained in a regulated temperature chamber. Power was supplied to the system through its cable inserted in a stuffing tube. Current drain and output noise were monitored during the tests. The following apparatus was used:

   Temperature Chamber - Delta Design Inc. MK-2300.

   Timer - Mark-Time (windup).

   Various electronic monitoring instruments in current calibration period.

b. Altitude simulation was obtained by placing the system inside a vacuum bell jar. Power and signal were transmitted via a feed-through connector in the base of the vacuum system. Pressure used for 100,000 feet equivalent altitude was 0.33 inches Hg and for 50,000 feet was 3.5 inches Hg. The following apparatus was used:

   Vacuum System - NRC Equipment Co.

   Differential Pressure Gauge - Meriam Instrument Co. Manometer Model 30E B 25.

   Reference Pressure Gauge - Cenco 76890 Mercury Barometer.

   Various electronic monitoring instruments in current calibration period.

4.3.4 Re-testing

The system was re-tested after completion of all qualification tests described in Secs. 4.3.2 and 4.3.3. A comparison of the measured results before and after exposure to the test conditions is presented in Table 4.

T A B L E 4

	BEFORE (22 Nov.)	After (6 Dec.)	CHANGE
Insulation Resistance	>900 mohm	>900 mohm	0
Clipping Level	5.367 VDC	5.369 VDC	+2 mV
Regulation 31 VDC	5.369 VDC	5.369 VDC	0
25 VDC	5.367 VDC	5.368 VDC	+1 mV
Output Bias	2.502 VDC	2.499 VDC	-3 mV
Sensitivity re 1 Volt (Full Scale)	-1.03 dB	-0.60 dB	+.43 dB
Noise re 1 Volt	-45 dB	-45 dB	0
Input Current	10.5 mA	10.6 mA	+.1 mA

The effect of altitude on sensor sensitivity was determined by placing the sensor and an electrostatic actuator, Bruel and Kjaer type 4142, in a bell-jar and changing the pressure to corresponding altitudes up to 100,000 ft. Two sensor systems evaluated showed a 1/2 dB and a 1 dB decrease between ambient pressure and 0.3 inch Hg (100 k Ft).

5. CONCLUSIONS

Seven Model 372 Acoustic Transmission Detection Systems have been fabricated as required by NAS 1-8472. Each of these systems has passed the required Quality Control tests. In addition, one system, chosen randomly, has passed flight-proof tests for the Pacemaker vehicle.

REFERENCES

1. Heller, H.H. Frequency Response of Acoustic Probes for Measuring Pressure Fluctuations on a Hypersonic Re-entry Vehicle. Bolt Beranek and Newman Inc. Report No. 1498, 3 May 1967.

2. Bies, D.A. A Review of Flight and Wind Tunnel Measurements Boundary Layer Pressure Fluctuations and Induced Structural Response. Bolt Beranek and Newman Inc. Report No. 1269, Contract NAS-1-5120, LRC Report, 28 January 1966.

3. Fluctuating Pressure Measurements on a Slender Cone Model in a Mach 3 Flow. Bolt Beranek and Newman Inc. Technical Manual No. 1, 29 March 1968.

4. Final Report for NAS 1-7439 Development of an Acoustic Flow Transition Detector for Re-Entry Spacecraft. Prepared for NASA Langley Research Center by AVCO, Missile Systems Division, Wilmington, Massachusetts, March 1968.

APPENDIX A

Quality Control Test Procedures

DATE 11/9/68
ORIGINATOR [signature]
APPROVAL Ed Starr
REVISION ________

TSS-5 372A No. 4

FINAL QUALITY CONTROL TEST PROCEDURE

Objective: To measure the mechanical and electrical characteristics of the 372A Miniature Transition Measuring System in respect to the design criteria and to assure that all parameters are within the prescribed limits.

System(s) to be Tested: 372A Transition Detector (Boundary Layer Flow) D-10372, consisting of (1) a signal conditioner D-20093 and (2) a sensor assembly D-20096.

Environmental Conditions Required: Ambient temperatures ($60^{\circ}F$ to $80^{\circ}F$). Clean area.

Note: Equipment log sheet (attached) must be completed.

I. Test Equipment Required:

A.	Precision Power Supply	Power Designs 2005
B.	Oscilloscope	TEK RM503
C.	Attenuator	Daven T-693-R
D.	AC VTVM	Ballantine 300H
E.	600/6 Ohm Termination	HP 11047A
F.	Triple Beam Balance Scale	Central Scientific

G.	Gage Block	BBN No.1
H.	Micrometer (1 inc.)	
I.	X10 Magnifier	
J.	Test Cable	BBN 372A No. 1
K.	Test Cable	BBN 372A No. 2
L.	Oscillator	HP 202 CR
M.	Power Supply	HP 721A
N.	VOM	Triplett 630NA
O.	Pistonphone	BK 4220
P.	Barometer	BK 0Z0001
Q.	Steel Rule	Lufkin No. C-2105R
R.	Test Fixture	BBN TF-007
S.		

II. Mechanical/Visual Inspection:

A. Weight

1. Using Triple Beam Balance scale weigh conditioner than sensor assembly.

Record actual weights on attached data sheet and note total does not exceed the prescribed limit.

B. Mechanical

1. Using Gage Block, Micrometer, and Steel Rule make all measurements as indicated on attached drawing (D-10372).

Record actual measurements on the attached data sheet and note they do not exceed the prescribed limits.

C. Visual

1. Check proper connector orientation (Reference attach drawing {D-10372}).

2. Check proper engraving J1 P1 location (Reference attached drawing {D-10372}).

3. Using X10 Magnifier inspect all connectors (conditioner and sensor assembly) note all pins and sockets are bright and clean and the contact springs are not missing or broken.

III. Insulation Resistance:

A. Connect test fixture and system as shown in Figure A-1.

1. Set "meter test" switch to on.

   a. Press button marked "test" and note meter reads approximately full scale.

2. Set "meter test" switch to off.

   a. Press button marked "test" and note meter reads less than 1 minor division.*

*Equivalent to 900 Mohms at 50 VDC.

Record actual result on the attached data sheet and note it is within the prescribed limit.

IV. Clipping Level

A. Gain Adjust

1. Connect conditioner and test equipment as shown in Figure A-2.

2. Adjust oscillator frequency controls to "1000" Hz.

3. Set attenuator controls to 00.0 dB.

4. Adjust oscillator level control for "0.0" dBv as read on AC VTVM.

5. Re-set attenuator controls to 10.0 dB.

6. Disconnect plus side of power supply.

   a. Set "meter range" switch to 30 VDC.

   b. Set power supply toggle switch to on.

   c. Rotate "voltage adjust" control for meter reading of 28 VDC.

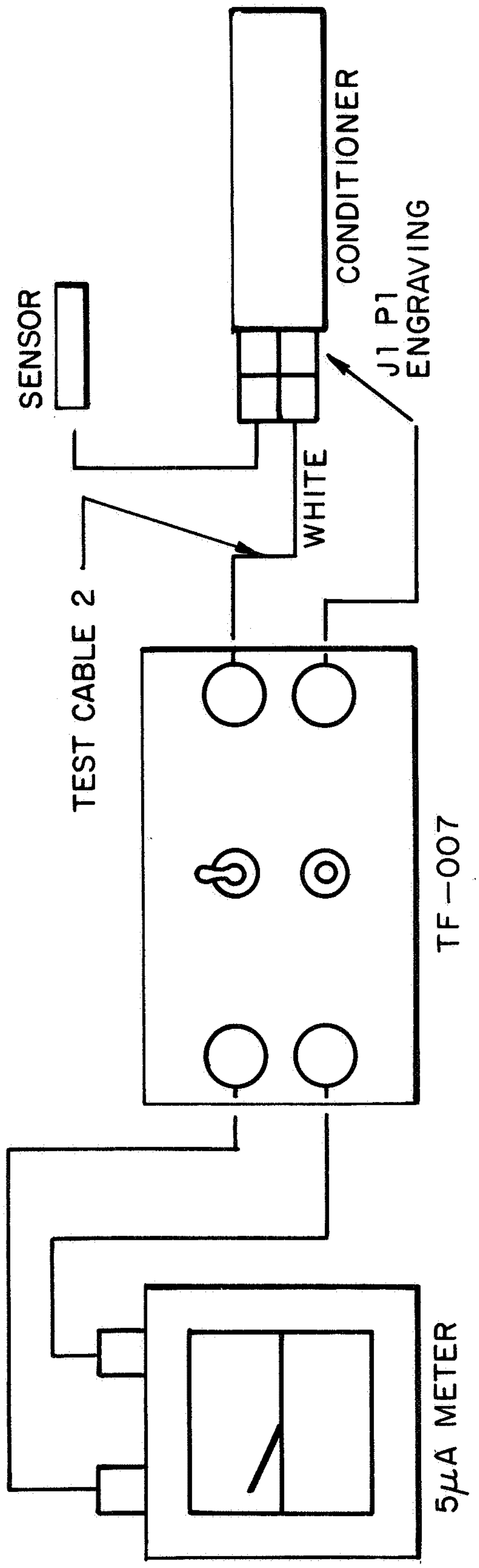


FIG. A-1 INSULATION RESISTANCE TEST EQUIPMENT CONFIGURATION

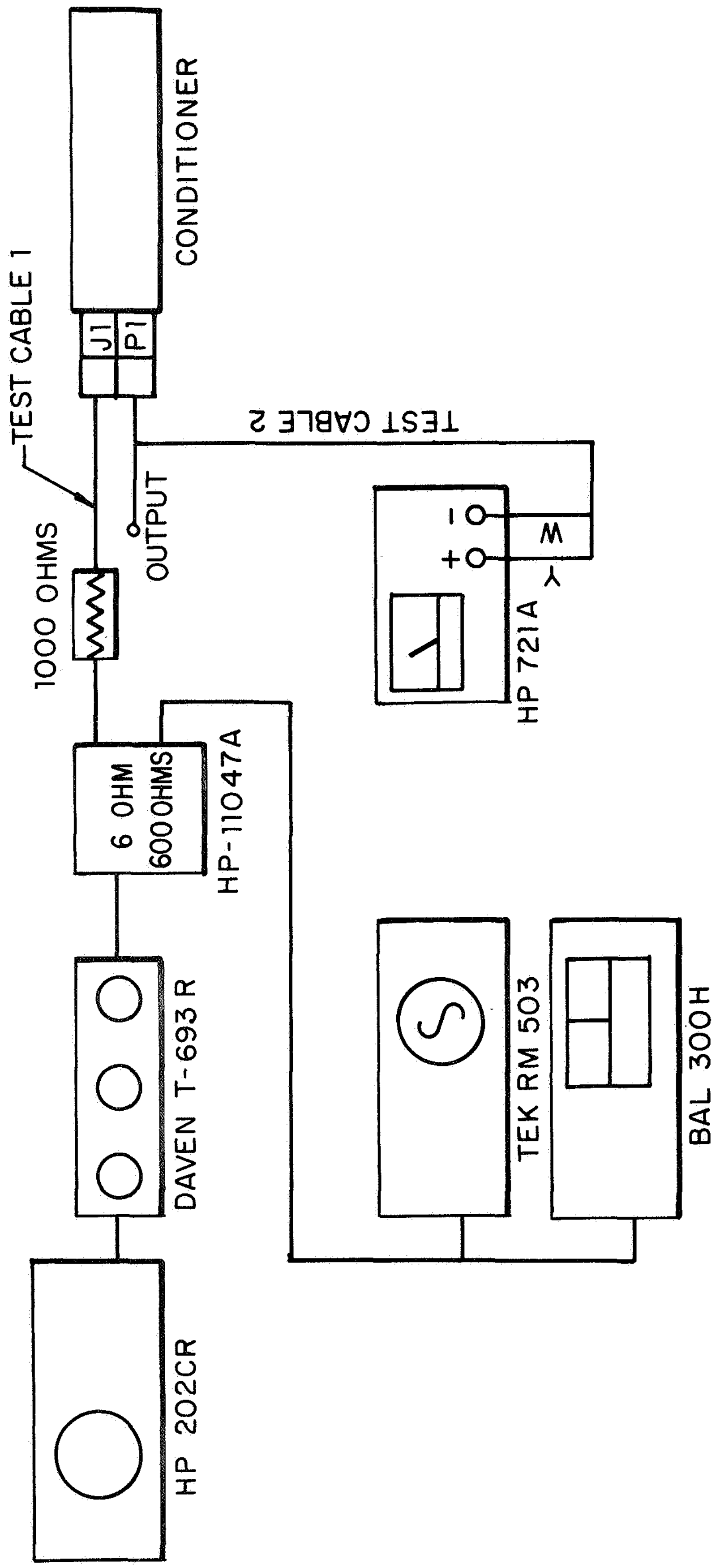


FIG.A-2 CLIPPING LEVEL TEST EQUIPMENT CONFIGURATION

d. Set power supply toggle switch to off.

e. Set "meter range" switch to 30 MA.

f. Set "short circuit current" switch to 25 MA.

g. Reconnect "plus" side of power supply.

h. Set power supply toggle switch to on.

Note power supply current meter reads less than 15 MA if not turn power supply off immediately!

7. Disconnect AC VTVM and oscilloscope from 600/6 ohm termination.

8. Connect conditioner "output" to AC VTVM and oscilloscope.

   a. Set oscilloscope vertical sensitivity to 1 V/cm (AC coupled, 0 VDC at screen center).

   b. Set oscilloscope sweep speed to 1 MS/CM.

9. Adjust R9 for 0.0 dBv as read on AC VTVM.

   a. Note waveform displayed on oscilloscope is undistorted.

B. Clipping Level Measurement

1. Set attenuator controls to 00.0 dB.

2. Note Waveform displayed on oscilloscope has positive and negative clipping.

3. Adjust precision power supply to 5.375 VDC.

4. Disconnect conditioner output common from oscilloscope.

5. Connect precision power supply common to conditioner output common.

6. Connect plus side of precision power supply to oscilloscope common.

7. Adjust oscilloscope vertical sensitivity to 10 MV/CM (DC coupled, 0 VDC at screen center).

8. Re-adjust precision power supply so that top of clipped waveform is displayed exactly in center of screen.

Record final setting of precision power supply on the attached data sheet and note it is within the prescribed limits.

V. Regulation

A. Connect VOM (60 VDC scale) across power supply output terminals.

1. Rotate power supply "voltage adjust" control for VOM reading.of 31 VDC.

2. Re-adjust precision power supply so that top of clipped waveform is again displayed exactly in center of screen.

Record final setting of precision power supply on the attached data sheet and note it is within the prescribed limits.

3. Rotate power supply "voltage adjust" control for VOM reading of 25 VDC.

4. Re-adjust precision power supply so that top of clipped waveform is again displayed exactly in center of screen.

Record final setting of precision power supply on the attached data sheet and note it is within the prescribed limits.

5. Rotate power supply "voltage adjust" control for VOM reading of 28 VDC.

VI. Output Bias

A. Set attenuator controls to 111 dB.

1. Adjust precision power supply so that oscilloscope trace is displayed exactly in screen center.

Record final setting of precision power supply on the attached data sheet and note it is within the prescribed limits.

VII. Sensitivity Adjust

A. Set power supply toggle switch to "off".

1. Disconnect precision power supply "common" from conditioner output common.
2. Disconnect "plus" side of precision power supply from oscilloscope common.
3. Reconnect conditioner output to oscilloscope and AC VTVM.
4. Disconnect test cable 1 from conditioner.
5. Connect sensor assembly to conditioner.
6. Insert sensor in pistonphone.
7. Set pistonphone switch to "measure".

B. Set power supply toggle switch to "on".

1. Adjust R9 so that AC VTVM reads exactly -1.0 dBv.*

* Assuming pistonphone SPL equals 124.0 dB re $2 \times 10^{-4} \mu$ bar and a ambient pressure of 29.92 in. Hg. Record individual calibration of pistonphone and ambient pressure on attached data sheet. Read correction from B.K. Barometer (UZ0001). Add correction to individual calibration (resulting in actual sound pressure level). Adjust R9 for reading on AC VTVM reference equivalent 125.0 dB re $2 \times 10^{-4} \mu$ bar. Record actual AC VTVM reading.

Example:

Ambient Pressure	30.80 in Hg
Pistonphone SPL	124.0 dB re $2 \times 10^{-4} \mu$ bars
Correction	+.25 dB
Actual SPL	124.25 dB
Sensitivity set to	-0.75 dBv

VIII. Noise

A. Set pistonphone switch to "off".

Record AC VTVM reading on the attached data sheet and note it is within the prescribed limits.

IX. Input Power

A. Set power supply toggle switch to "off".

1. Connect VOM (120 MA/2 scale) in series with "plus" lead of power supply.

B. Set power supply toggle switch to "on".

Record VOM reading on the attached data sheet and note it is within the prescribed limits.

This completes final test. Complete the equipment log sheet. Place Glyptol on R9 and route system and data to CS-4.

TEST RESULTS

TSS-5 372A No. 4R

372A Transition Detector (Boundary Layer Flow)

D-10372 SN ______________

Consisting of:

1. Signal Conditioner D-20093

   SN ______________

2. Sensor Assembly D-20096

   SN ______________

Date ____________________

Tested By _______________

Time Required ___________

Note: Equipment log sheet (attached) must be completed.

TEST EQUIPMENT

Model	SN	Manufacturer	Last Calibration

____	____	____	____
____	____	____	____
____	____	____	____
____	____	____	____
____	____	____	____
____	____	____	____
____	____	____	____
____	____	____	____
____	____	____	____
____	____	____	____

All above test equipment is within a valid calibration period.

Certified By ____________________
(Authorized Representative Test Equipment Engineering)

II. A. Weight

Sensor	______ lbs	
Conditioner	______ lbs	Limit
Total	______ lbs	<.25 lbs

B. Mechanical

Conditioner

		Limit			Limit
A	______	1.480 ±.020 (Gage)	C	______	2.12 ± .010 (Gage)
B	______	2.490 ±.030 (Gage)	D	______	1.12 ± .010 (Gage)

		Limit
E	______	.620 ± .010 (Meas.)

Sensor

	Limit		Limit
F______	.250 ± .001	G______	.887 ± .005

	Limit
H______	36" ± 1"

C. Visual

Connector Orientation	______________
"J1 P1" Location	______________
X10 Magnifier Inspect.	______________
Contact Springs	______________

III. Insulation Resistance

	Limit
__________Div	1 minor division

IV. Clipping Level

	Limit
__________VDC	5.375 ± 300 MV

V. Regulation

	Limit
31 VDC__________VDC	5.375 ± 350 MV
25 VDC__________VDC	5.375 ± 350 MV

VI. Output Bias

	Limit
__________VDC	2.500 VDC ± 150 MV

VII. Sensitivity Adjust

Ambient Pressure	__________in. Hg.
Pistonphone SPL	__________dB re 2 x 10^{-4} µbar
Correction	__________dB
Actual SPL	__________dB re 2 x 10^{-4} µbar
Sensitivity Set To	__________dBv

VIII. Noise

	Limit
____________ dBv	<-36 dBv

IX. Input Power

	Limit
____________ MA	<15 MA

R9 Glptol ___________

Equipment Log Sheet Complete ___________

Routed to CS-4 __________

EQUIPMENT LOG SHEET

☐ FLT ☐ PROTO

PROJECT | COMP./SUB-SYS. NAME | END USE | DWG. NO. | SERIAL NO. | MANUFACTURER | NEXT HIGHER ASSY.

(1) Date	(2) Elapsed Time/ Cycles	(3) Accum. Time/ Cycles	(4) Type of Operation or Test	(5) Failure Report No.	(6) (1) Remarks	(7) Recorded By

(1) For "Remarks" requiring more than one line, write completely across the page, disregarding the divisions on the second line.

Sheet______of______

DATE 10/22/68
ORIGINATOR [signature]
APPROVAL [signature]
REVISION ___

TSS-3 372A No. 1

INPROCESS QUALITY CONTROL TEST PROCEDURE

Objective: To measure the electrical characteristics of the 372A D-20096 sensor assembly in respect to the design criteria and to assure that all applicable parameters are within the prescribed tolerances.

References:

I. Test Equipment Required

A.	Oscillator	Hp 202CR
B.	Decade Resistor	GR 1432M
C.	Current Source	BBN
D.	AC VTVM	Bal 300H S/2
E.	Pistonphone	B+K 4220
F.	Adapter	BBN
G.	8μf Capacitor	BBN

H.	Sound Level Meter	GR 1551 B-C
I.	Beat Frequency Oscillator	B+K 1014
J.	Graphic Level Recorder	B+K 2305
K.	Microphone Calibration Apparatus	B+K 4141
L.	Electrostatic Actuator	B+K UA0033
M.	D-20096 Adapter	BBN
N.	Random Noise Generator	GR 1381
O.	Octave Band Analyzer	B+K 1612
P.	Power Amplifier	MC 40
Q.	Shaker	Goodman V50
R.		
S.		
T.		
U.		

II. Output Impedance

A. Connect test equipment as shown in Figure A-3.

1. Set oscillator frequency control to 1000 Hz.

2. Set oscillator level control so that AC VTVM reads exactly 1 VRMS.

3. Adjust decade resistor controls to 98400 Ohms.

B. Connect oscillator output to decade resistor and disconnect AC VTVM from oscillator output and reconnect to junction of current source, decade resistor, and sensor.

1. Set current source off/on switch to on.

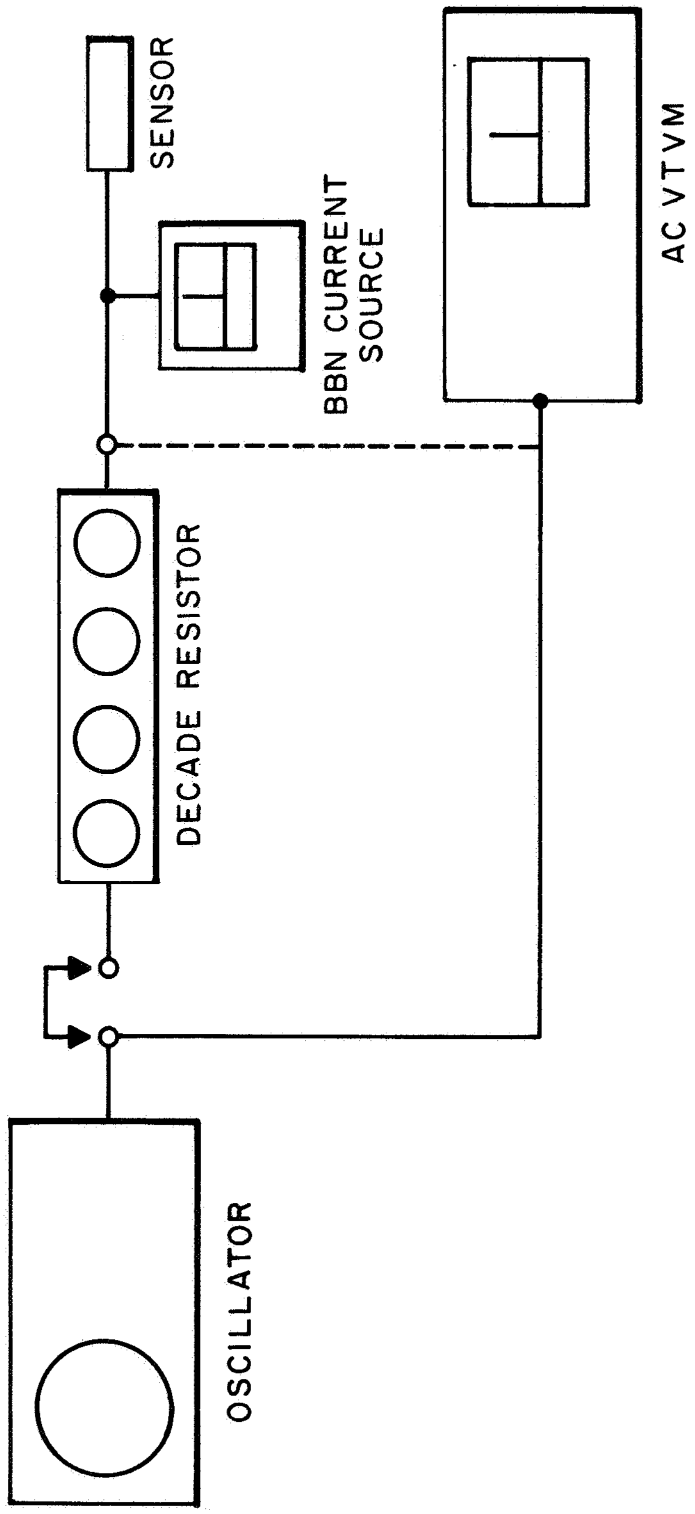


FIG.A-3 TRANSDUCER OUTPUT IMPEDANCE TEST EQUIPMENT CONFIGURATION

Record AC VTVM reading on the attached data sheet and note it is within the prescribed limits. Note: The transfer function is 1 MV/100 ohms.

III. Sensitivity

A. Calibrate sound level meter so that 1 VRMS at 250 Hz is equivalent to 130 dB on 20 KC weighting and meter slow.

B. Connect test equipment as shown in Figure A-4.

1. Set pistonphone test/measure/off switch to measure.

2. Set current source on/off switch to on.

3. Adjust sound level meter attenuator for meter reading between 0 and + 10 dB.

Record sound level meter reading and attenuator setting on the attached data sheet and note it is within the prescribed limits.

Note: To obtain sensitivity in dB re 1V/μbar, subtract sound level meter reading plus the attenuator setting from 130 dB then add 50 dB. The negative value of this sum is the sensitivity.

Example:	Meter reading	+6
	Attenuator setting	60
		66
		130
		- 66
		64
		+ 50
		114 dB re 1V/μbar

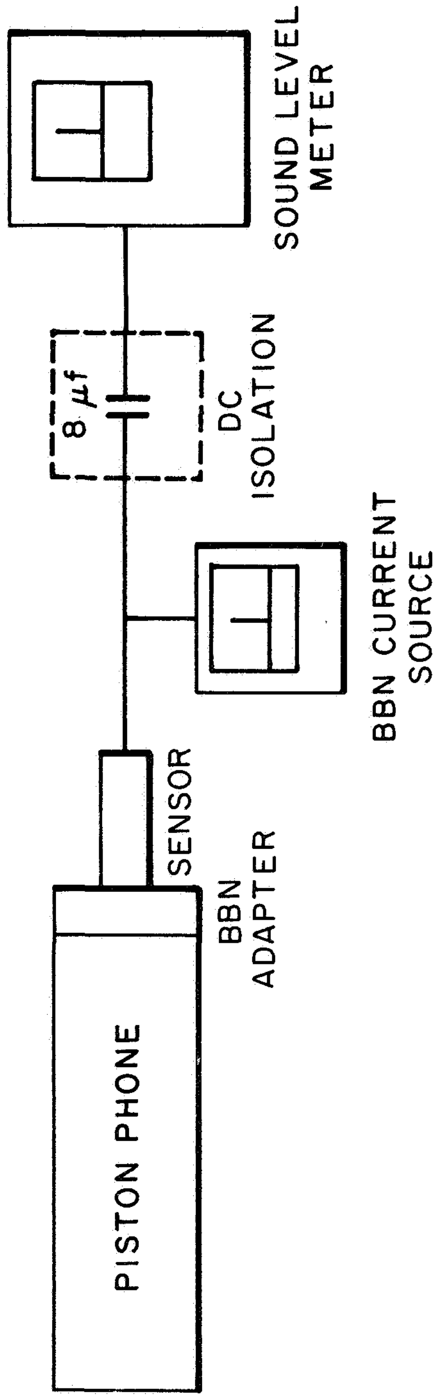


FIG. A-4 TRANSDUCER SENSITIVITY TEST EQUIPMENT CONFIGURATION

IV. Noise

A. Set pistonphone test/measure/off switch to off.

Record sound level meter and attenuator setting on the attached data sheet and note it is within the prescribed limits.

V. Frequency Response/Sensitivity

A. Connect test equipment as shown in Diagram 3.

1. BFO controls setting.

a. "Power" switch to on.

b. "Clutch" switch to off.

c. "Frequency Increment" to 0 Hz.

d. "Modulation Frequency" to Mod. off.

e. "Modulation Swing c/s" to 0.

f. "Compressor Speed dB/sec" to comp off.

g. "Frequency Scale Adjustment" adjust for Ø beat with "Frequency Dial" set to 60 Hz, output voltage control set for meter center scale and power frequency beat button Depressed.

h. "Attenuator Switch" to 12000.

i. "Matching Impedance" set to 600Ω.

j. "Compressor Voltage" set to 0.

k. "Output Voltage" set for meter reading of 120 VRMS at 1000 Hz.

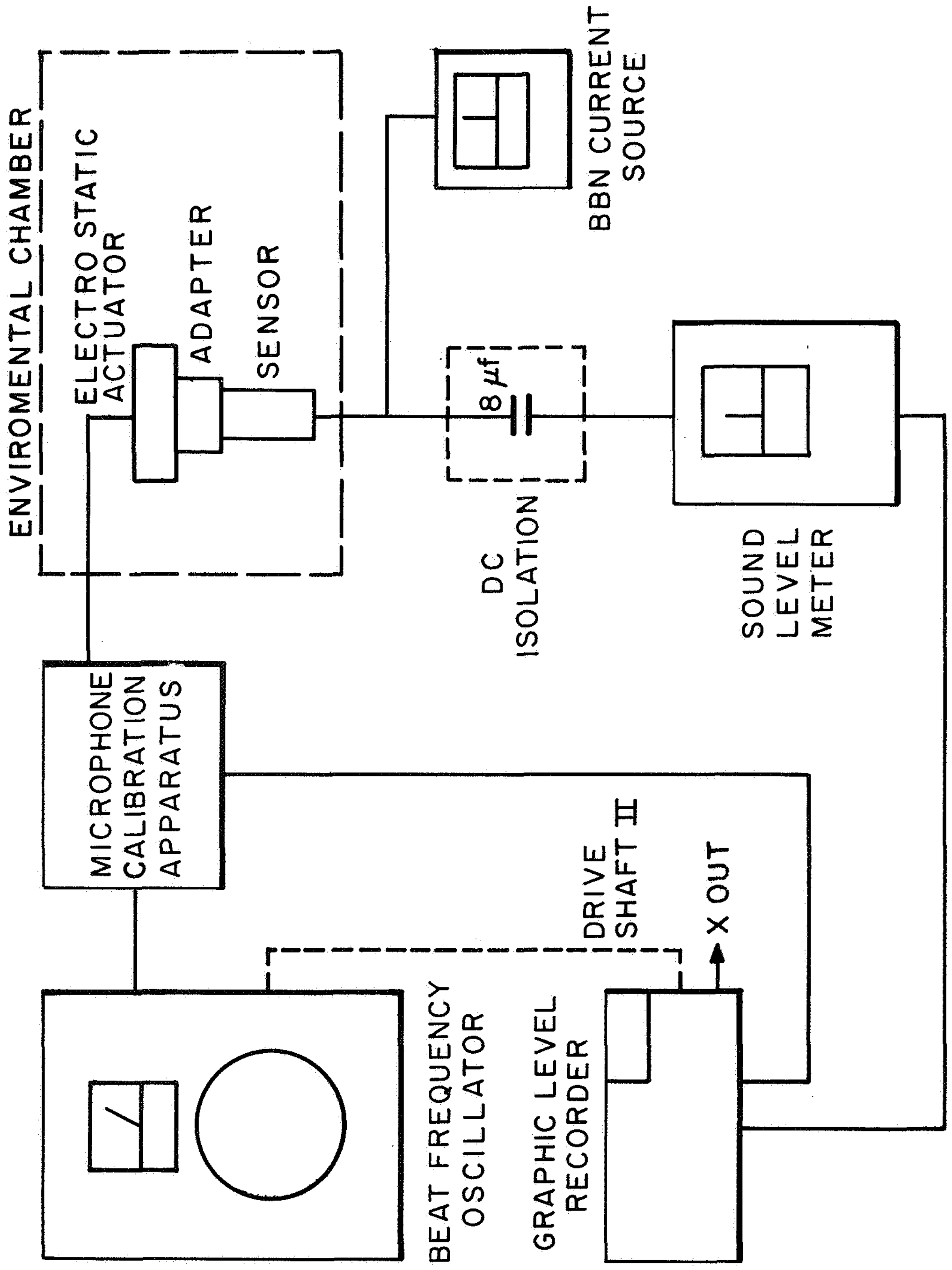


FIG.A-5 TRANSDUCER FREQUENCY RESPONSE TEST EQUIPMENT CONFIGURATION

2. GLR control settings:

   a. Potentiometer range set to 25 dB. (25 dB pot used)

   b. "Rectifier Response" to RMS.

   c. "Lower Limiting Frequency c/s" to 10.

   d. "Writing Speed MM/sec" to 25/50.

   e. "Power" to on.

   f. "Motor" to off.

   g. "Paper Speed MM/sec" to 10/1.

   h. "Drive Shaft Speed RPM" to 12.

3. Microphone Calibration Apparatus.

   a. "Power" to on.

4. Sound Level Meter

   a. "Meter" switch set slow.

   b. "Weighting" switch set 20 KC.

   c. "Attenuator" adjust for Mid Scale with BFO set to 1000 Hz.

5. Adjust GLR "Input Potentiometer" and "Input Attenuator" for 20 dB stylus deflection with BFO Frequency Control set to 1000 Hz.

6. Align chart paper and frequency dial, set "clutch switch" to on (BF), and oven controls to off. Start motor and run frequency response (start paper at 10 Hz and record to 40 KHz, 10 to 20 Hz and 20 KHz to 40 KHz deflections will represent the noise floor) at 70°F (Green) 20°F (Blue) and 160°F (Red).

Allow 15 minutes for stabilization at each temperature. Record results on the attached data sheet and note they are within the prescribed limits. Attach chart to data sheet.

VI. <u>Vibration Sensitivity</u>

A. Connect test equipment as shown in Diagram 4.*

B. Excite sensor at the levels, frequencies, and modes as indicated on Diagram 4.

Record readings obtained on sound level meter (calibrated for 1 VRMS at 130 dB) on the attached data sheet.

* When inserting sensor in test fixture apply a coating of grease (vaseline) around the stainless steel body of the sensor, (not around the black area) and then screw split nut against sensor body firmly.

This completes inprocess testing. Place data sheet in envelope with sensor. Complete systems status sheet and route sensor to TSS-5.

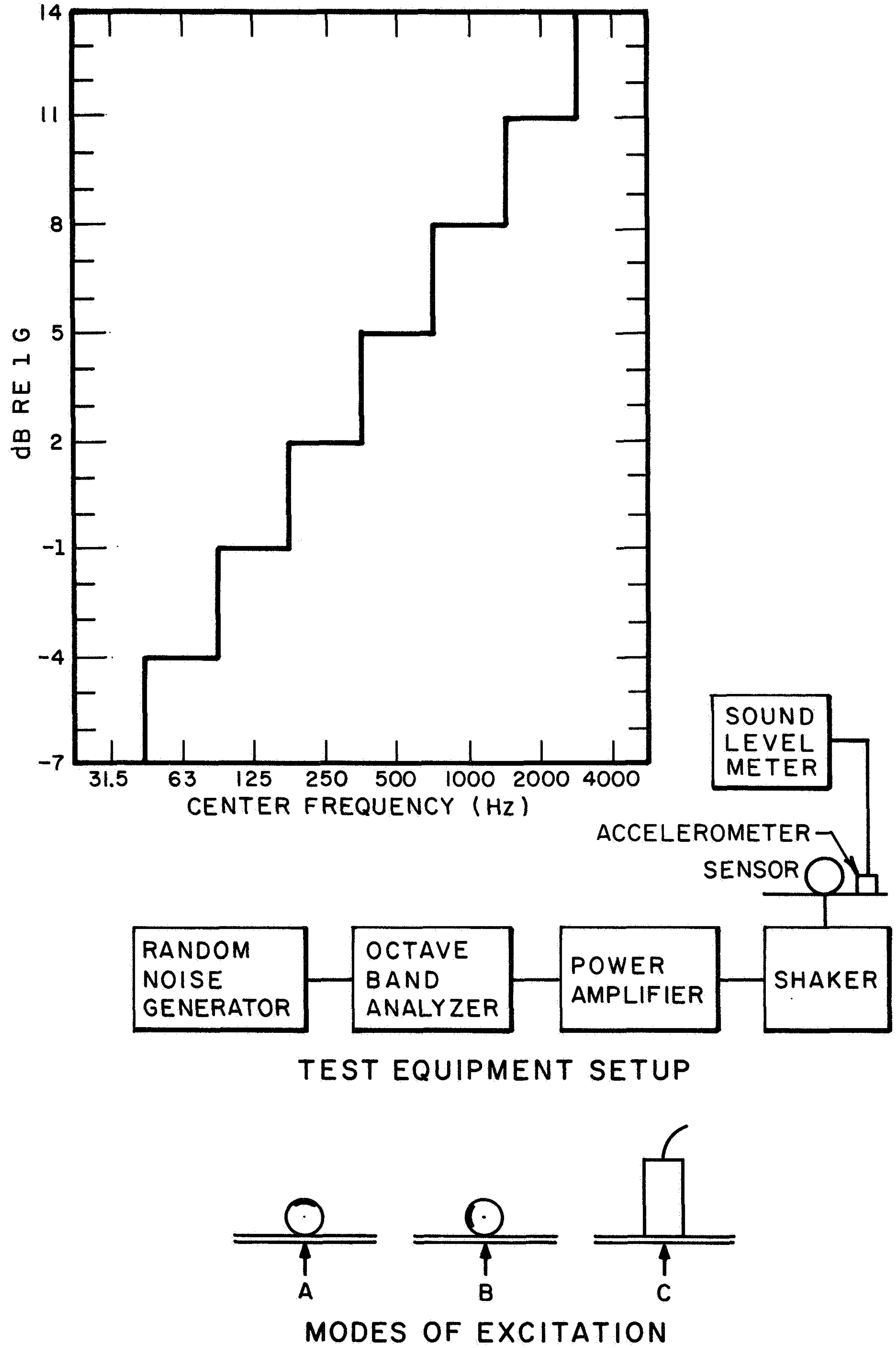


FIG.A-6 TRANSDUCER VIBRATION SENSITIVITY TEST EQUIPMENT CONFIGURATION.

TEST RESULTS

TSS-3 372A No. 1
Rev ____________________

MINIATURE TRANSITION MEASURING SYSTEM SENSOR ASSEMBLY

372A D-20096 SN ______________

DATE ______________

TESTED BY ______________

TIME REQUIRED ______________

II. Output Impedance

	Limits
____________ MV	10 MV ± 5 MV

III. Sensitivity

	Limits
____________ dB	70 dB $^{+12}_{-0}$

IV. Noise

	Limits
____________ dB	Less than 40 dB

V. Frequency Response/Sensitivity

			Limits
$70^{\circ}F$	100 Hz to 4000 Hz	_____ dB(spread)	Flat within 3 dB
	20 Hz to 40 Hz	_____ dB (slope)	6 dB slope ± 1 dB
	sensitivity 1000 Hz	_____ dB	Reference
$160^{\circ}F$	100 Hz to 4000 Hz	_____ dB(Spread)	Flat within 3 dB
	20 Hz to 40 Hz	_____ dB (Slope)	6 dB slope ± 1 dB
	sensitivity 1000 Hz	_____ dB	Reference $^{+.5}_{-1.5}$ dB
$20^{\circ}F$	100 Hz to 4000 Hz	_____ dB(Spread)	Flat within 3 dB
	20 Hz to 40 Hz	_____ dB (Slope)	6 dB slope ± 1 dB
	sensitivity 1000 Hz	_____ dB	Reference $^{+.5}_{-1.5}$ dB

VI. Vibration Sensitivity

Center Frequency	Correction (dB)	Levels (Equivalent SPL/G) A	Limits	B	Limits	C	Limits
31.5	+7		110		115		125
63	+4		110		115		125
125	+1		110		115		125
250	-2		110		115		125
500	-5		110		115		125
1000	-8		110		115		125
2000	-11		110		115		125
4000	-14		110		115		125

Record Actual Meter Reading on Data Sheet

For Reduction to SPL/G:

1. Apply correction
2. Subtract result from sensitivity (part III)
3. Subtract above result from 124

Example:

1. 52 (meter reading) - 7 (correction) = 45
2. 76 (sensitivity) - 45 = 31
3. 124 - 31 = 93 dB SPL/G

Date 10/22/68
Originator [signature]
Approval [signature] 10/28/68
Revision ______

TSS-2 372A No. 1

INPROCESS QUALITY CONTROL PROCEDURE

Objective: To measure the mechanical and electrical characteristics of the 372A Signal Conditioner in respect to the design criteria and to assure that all applicable parameters are within the prescribed tolerances.

References:

I. Test Equipment Required:

A.	Beat Frequency Oscillator	GR	1304B
B.	Attenuator	Daven	T-693-R
C.	600/6 Ohm Pad	HP	11047-A
D.	1K Ohm 1% Resistor	BBN	N/A
E.	Decade Resistor	GR	1432-M
F.	Decade Resistor	GR	1432-N
G.	Oscilloscope	TEK	RM-503
H.	Precision Power Supply	PD	2005
I.	Power Supply	HP	721A

J.	Graphic Level Recorder	GR	1521A
K.	AC VTVM	Bal	300H S/2
L.	Volt/Ohm Meter	Trip	630 NA
M.	Test Cable	BBN	372A No. 1 *
N.	Test Cable	BBN	372A No. 2 *
O.	$8\mu f$ cap.	BBN	

II. Mechanical/Visual Inspection (1)

A. Inspect for correct connector orientation (see work instruction MS-1, No. 1) and the pins and sockets are clean and not distorted.

B. Inspect all solder connections in respect to NASA Criteria (NASA Qualified Personnel Only).

III.(A) Output Bias and Clipping Level Adjust

A. Connect Test Equipment as shown in Figure A-8.

1. Connect decade resistor 1 to "B" (Junction of A2 R12 and base of Q3) and "A" (Junction A2 R7 and A2 C3).

   a. Set decade resistor 1 controls to 13K ohms.

2. Connect decade resistor 2 to "A" (junction of A2 R7, C3) and "C" (open side of A1 R16).

   a. Set decade resistor 2 controls to 3.9K ohms.

3. Set BFO Frequency control to 1000 Hz.

4. Set Attenuator controls to 0 dB.

5. Connect AC VTVM to HP 11047A 600 ohm output.

   a. Adjust BFO level control (5 volt range) so that AC VTVM reads exactly 0 dBv.

*See Figure A-7.

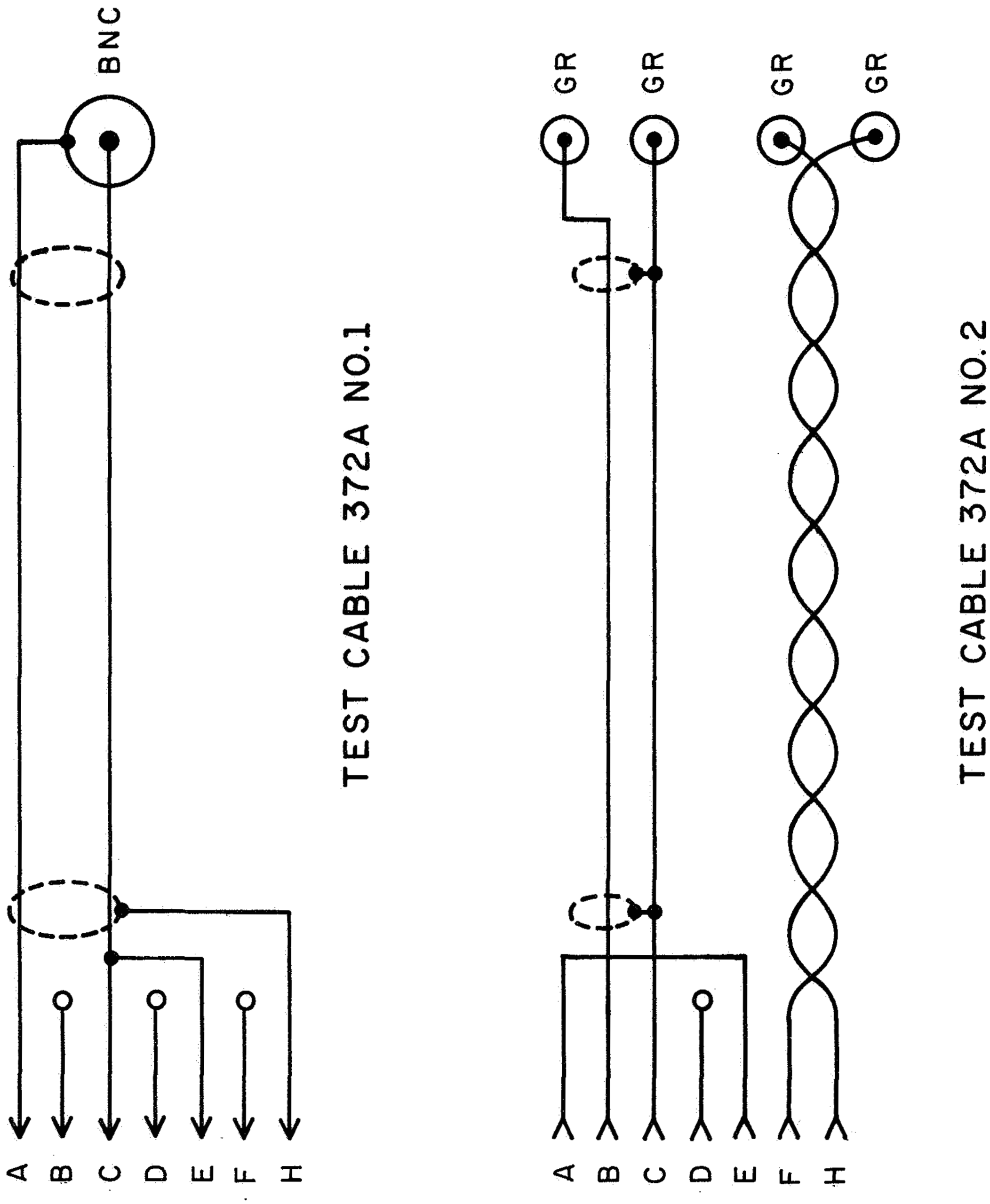


FIG.A-7 SIGNAL CONDITIONER TEST CABLES

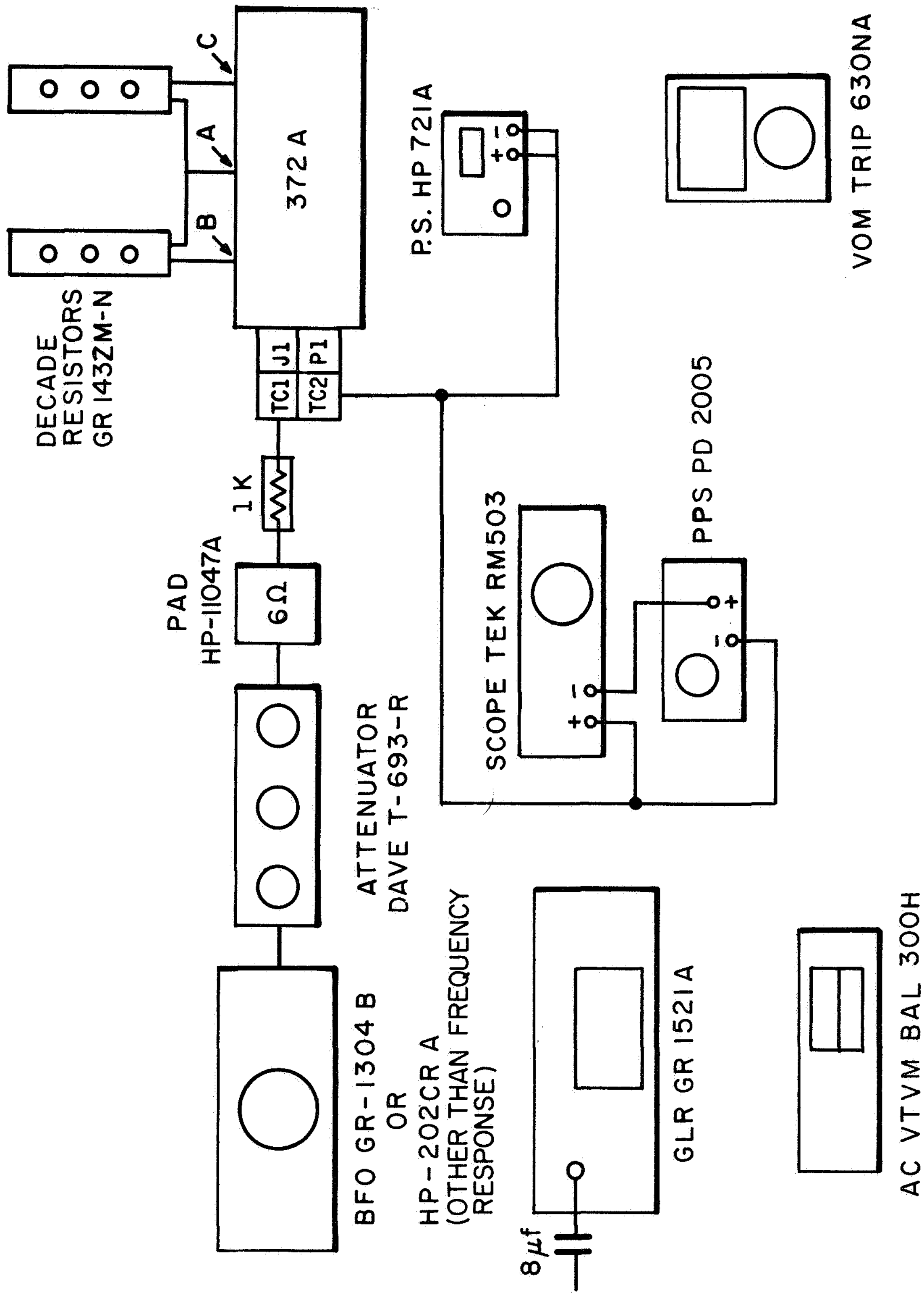


FIG.A-8 SIGNAL CONDITIONER TEST EQUIPMENT CONFIGURATION

6. Set Attenuator controls to -20 dB.

7. Adjust Precision Power Supply to 0.000 VDC.

8. Momentarily disconnect "plus" side of 721A, turn "on", adjust to 28 VDC, turn "off", and reconnect plus side.

   a. Set "meter range" switch to 30 MA.

   b. Set short circuit current switch to 25 MA.

9. Turn 721A "on": Note Current Meter Reads Less Than 15 MA, If Not Turn 721A "Off" Immediately.

   a. Set oscilloscope vertical sensitivity to 1 V/CM.

   b. Set oscilloscope sweep speed to 1 MS/CM.

   c. Set 0 volts for bottem of scope.

10. Adjust R9 for 3V pk-pk on scope.

   a. Set 0 volts for scope center.

   b. Set attenuator to -111 dB.

   c. Adjust precision power supply for 2.50 VDC.

   d. Adjust r decade 2 for oscilloscope beam center (adjusting vertical sensitivity to final setting of 10 MV/CM, checking DC Bal as required).

   e. Set precision power supply to 5.375 VDC.

   f. Set attenuator for flat positive clipping (10 dB). Adjust scope sensitivity as required.

   g. Adjust R decade 1 for oscilloscope beam center (adjusting vertical sensitivity to final setting of 10MV/CM, checking DC Balance as required. Record R decade 1 settings on data sheet.

12. Re-adjust attenuator to -111 dB.

    a. Reset precision power supply to 2.50 VDC.

    b. Re-adjust r decade 2 for oscilloscope beam center (adjusting vertical sensitivity to final setting of 10 MV/CM, checking DC balance as required. Record R-decade 2 setting on data sheet.

This completes output bias and clipping level adjustments. Disconnect conditioner from test setup and record final settings of R decade 1 and R decade 2 on data sheet. *Replace R decade 1 with R10 (1/4 5% comp resister) and R11 (RN65C) the sum of these two resisters shall be equivalent to final setting of R decade 1 with R11 making up at least 75% of the total value. Replace R decade 2 with R3 (closest 1/4 watt 5% resister to final setting of R decade 2. Record final selected values on data sheet. Replace jumper from A1 E6 to A2 E2 with bus wire and spacer. Place eastman 910 on top surface of R9 and align PWB boards.

* To be accomplished by NASA Qualified Solderer only Reference Dwg No. D20094.

III.(B) <u>Visual/Mechanical Inspection</u> (2)

* Carefully inspection recent solder joints and note assembly fits completely though gage block. * To be accomplished by NASA Qualified Solderer Only.

IV. <u>Final Clipping and Bias Measurement</u>

A. Reconnect conditioner in test setup.

1. Measure bias and clipping level using method described in Part III.A

2, Record values on data sheet and note they are within prescribed tolerances.

V. Regulation

A. Adjust test equipment for clipping level display on scope.

B. Connect VOM meter (60 VDC scale) across 721A and adjust 721A to 31 VDC.

C. Re-adjust precision power supply for oscilloscope null and record dial setting on data sheet.

D. Re-adjust 721A for 25 VDC.

E. Re-adjust precision power supply for oscilloscope null and record dial setting on data sheet.

F. Note both dial settings are ± 60 MV from original dial setting.

G. Re-adjust 721A to 28 VDC.

VI. Input Current

A. Disconnect precision power supply from test setup and connect conditioner output directly to oscilloscope and AC VTVM.

B. Turn 721A off and connect VOM ($\frac{120}{2}$ scale) in series with plus side of supply.

C. Set attenuator to 111 DB turn 721A on and record VOM reading and note it is less than the prescribed limit.

D. Set attenuator to 0 dB, record VOM reading and note it is less than the prescribed limit.

E. Turn 721A "off" and disconnect VOM. Reconnect plus lead to conditioner and turn 721A "On".

VII. Tranducer Current

A. Disconnect 1K ohm resistor from HP 11047A.

B. Connect VOM (1.2 MA scale) from 1K resistor shell and center.

C. Record VOM reading and note it is within the prescribed tolerance.

D. Disconnect VOM and reconnect 1K ohm resistor to HP 11047A.

VIII. Gain Range

A. Adjust R9 Max CW and note VTVM reading. Record on data sheet and note it is within the prescribed limit.

B. Set attenuator to -20 dB adjust R9 Max CCW and VTVM reading record on data sheet and note it is within prescribed limit.

IX. Noise

A. Re-adjust R9 slightly so that AC VTVM reads 0 dBv.

B. Disconnect 1K ohm resistor from HP 11047A and terminate 1K ohm resistor with shorting cap.

C. Record VTVM reading on data sheet and note it is within the prescribed limit.

D. Remove shorting cap and reconnect 1K ohm resistor to HP 11047A.

X. <u>Frequency Response</u>

A. Set attenuator to -10 dB and adjust R9 for 0 dBv on VTVM.

B. Connect GLR to conditioner output.

C. Adjust GLR level control so than pen deflects 17 dB (20 dB pot).

1. Set writing speed to 3.

2. Set damping control to center of range.

D. Set speed control to 1 and x 10.

E. Run frequency response (20 Hz to 20,000 Hz) at this speed marking 1 kc.

F. Using overlay note frequency response is within the limits.

XI. <u>Environmental Tests</u>

A. Place conditioner in chamber and set oven to 20°F.

1. Reconnect conditioner as shown in Diagram 1.

a. Allow 15 min. for temperature stabilization.

2. Recheck oscillator level at 1000 Hz at 600 Ohm output of HP 11047A. For 0 dBv/.

B. <u>Bias and clipping levels</u>.

1. Set attenuator to 111 dB.

a. Adjust precision power supply for oscill-oscope null.

b. Record dial reading on data sheet and note it is within prescribed limits.

C. Regulation

1. Connect VOM across 721A and adjust for 721A for 31V
   a. Readjust precision power supply for oscilloscope null.
   b. Record reading on data sheet and note it is within the prescribed limits.
2. Adjust 721A for 25V reading on VOM.
   a. Readjust precision power supply for oscilloscope null.
   b. Record reading on data sheet and note it is within the prescribed limits.
   c. Readjust 721A to 28 VDC and disconnect VOM.

D. Input Current

1. Disconnect precision power supply from test setup and connect conditioner output directly to O scope and AC VTVM.
2. Turn 721A off and connect VOM ($\frac{120}{2}$ MA scale) in series with plus side of supply.
3. Turn 721A "on", record VOM reading and note it is within the prescribed limit.
4. Set Attenuator to 111 dB, record VOM reading and note it is within the prescribed limits.
5. Turn 721A "off", disconnect VOM, reconnect "plus" lead to power supply.

E. Transducer Current

1. Disconnect 1K ohm resistor from HP 11047A.
2. Connect VOM (1.2/2 MA scale) to BNC resistor shell and center conductor.

3. Record VOM reading and note it is withing the prescribed limit.

4. Disconnect VOM and terminate 1K ohm resistor with a shorting cap.

F. Noise

1. Record AC VTVM reading and note it is in within the prescribed limit.

G. Gain

1. Disconnect shorting cap and reconnect 1K ohm resistor to HP 11047A.

2. Set attenuator to 10 dB.

3. Record AC VTVM reading and note it is within the prescribed limit.

H. Frequency Response

1. Connect conditioner output to GLR in series with $8\mu f$ capacitor.

2. Adjust GLR level control so that pen deflects 17 dB (use 20 dB GlR pot).

3. Set writing speed to 3.

4. Set damping control to center of range.

5. Set speed controls to 1 and x10 (or .5 and x10).

6. Run frequency response at this speed marking 1 KC.

7. Attach frequency response to data sheet using overlay to verify acceptability.

8. Set oven to $160^{\circ}F$ after allowing 15 minutes for stabilization repeat parts X1 A,B,C,D,E, F,G,H.

This completes this test. Place data sheet in envelope with conditioner (in plastic bag) complete systems status sheet. Route conditioner to TSS-4.

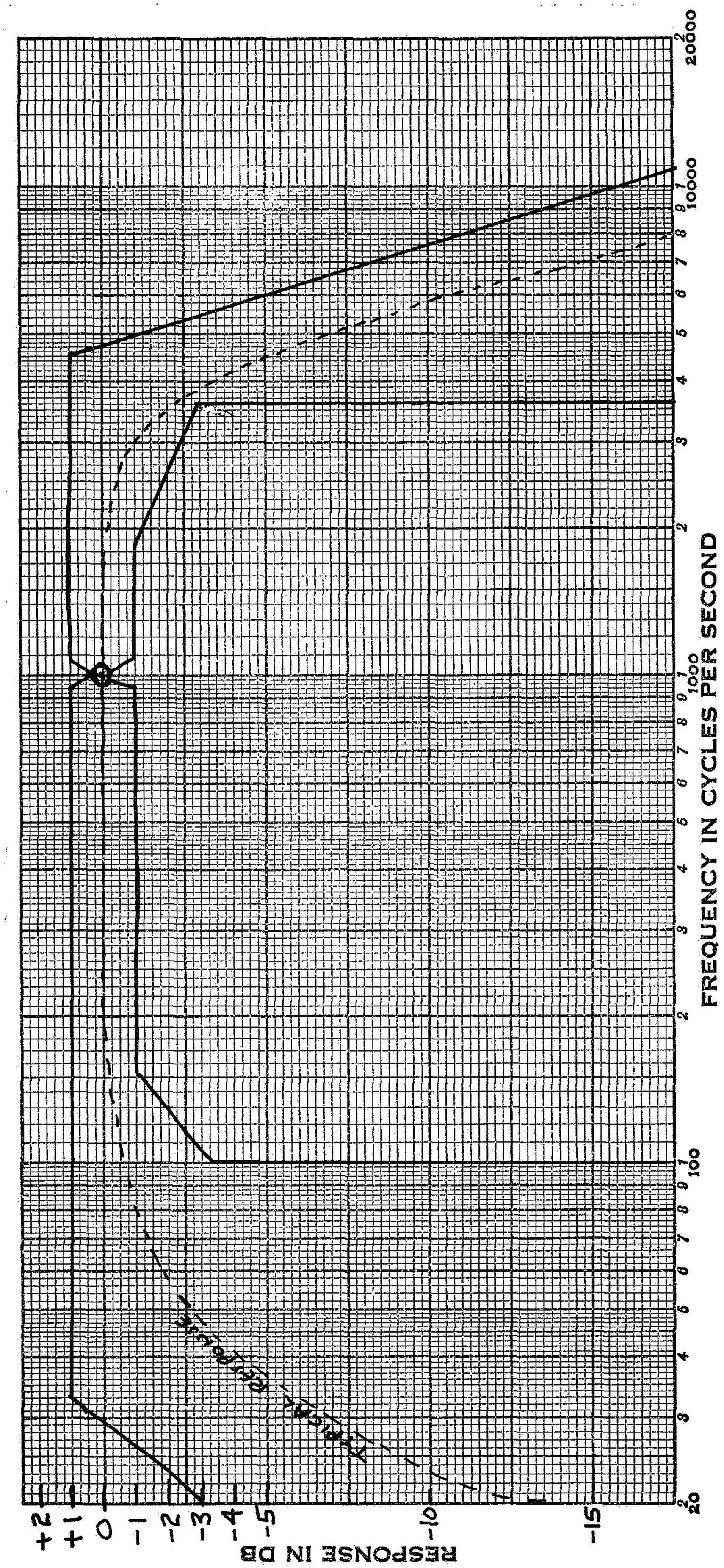


FIG.A-9 SPECIFICATION LIMITS - FREQUENCY RESPONSE MODEL 372A SIGNAL CONDITIONER

TEST RESULTS

TSS-2 372A No.1
Rev ______________

Miniature Transition Measuring Signal Conditioner
372A SN ________

Date ________________

Tested By ____________

Time Required _________

II. Mechanical/Visual Inspection (1)

A. Connector orientation ___________

B. Pins, sockets clean _____________

C. Solder connections ______________

______________________ NASA Qualified Inspector ______________ Date

III. Output Bias and Clipping Level Adjustment

11G R-Decade 1 setting ______________ohms

12B R-Decade 2 setting ______________ohms

Selected Values R10 __________ohms (5%)

R11 __________ohms (1%)

R3 __________ohms (5%)

Installation and Inspection

R10 __________

R11 __________

R3 __________

Jumper __________

Eastman 910 __________

____________________ NASA Qualified Solderer ________ Date ____________________ NASA Qualified Inspector ________ Date

IV. Final Clipping and Bias Measurement

		Limit
Clipping	________ VDC	5.375 VDC ± 0.1 VDC
Bias	________ VDC	2.500 VDC ± 0.05 VDC

V. Regulation

		Limits
31 VDC	________ VDC	Clipping Level ± 60 MV
25 VDC	________ VDC	Clipping Level ± 60 MV

VI. Input Current

		Limits
C	________ MA	11 MA ± 2 MA
D	________ MA	13 MA ± 2 MA

VII. Transducer Current

	Limits
________ MA	.5 MA ± 0.1 MA

VIII. Gain Range

		Limits
A	________ dBv	0 dBv $^{+0\ dB}_{-3\ dB}$
B	________ dBv	0 dV $^{+3\ dB}_{-0\ dB}$

IX. Noise

	Limits
________ dBv	-45dBv Max.

X. Frequency Response

Checked vs Overlay ________

IX. Environmental Test

B. Bias and Clipping Levels

			Limits
Clipping Level	$20^{o}F$	________VDC	5.375 VDC ± 0.25 VDC
	$160^{o}F$	________VDC	5.375 VDC ± 0.25 VDC

			Limits
Bias	$20^{o}F$	________VDC	2.500 VDC ± 0.15 VDC
	$160^{o}F$	________VDC	2.500 VDC ± 0.15 VDC

C. Regulation

			Limits
$20^{o}F$	31 VDC	__________VDC	Clipping Level ± 60 MV
$20^{o}F$	25 VDC	__________VDC	Clipping Level ± 60 MV
$160^{o}F$	31 VDC	__________VDC	Clipping Level ± 60 MV
$160^{o}F$	25 VDC	__________VDC	Clipping Level ± 60 MV

D. Input Current

			Limits
$20^{o}F$	__________	MA	13 MA ± 2 MA
$20^{o}F$	__________	MA	11 MA ± 2 MA
$160^{o}F$	__________	MA	13 MA ± 2 MA
$160^{o}F$	__________	MA	11 MA ± 2 MA

E. Transducer Current

			Limits
$20^{o}F$	__________	MA	0.5 MA ± 0.1 MA
$160^{o}F$	__________	MA	0.5 MA ± 0.1 MA

F. Noise

		Limits
$20^{o}F$	__________dBv	-45 dBv Max.
$160^{o}F$	__________dBv	-45 dBv Max.

G. <u>Gain</u>

			Limits
$20^{\circ}F$	________	dBv	0 dBv ± 0.2 dB
$160^{\circ}F$	________	dBv	0 dBv ± 0.2 dB

H. <u>Frequency Response</u>

$20^{\circ}F$ Checked vs Overlay ________

$160^{\circ}F$ Checked vs Overlay ________

System status sheet complete __________

System routed to TSS-4 ______________

Failure Report completed __________

APPENDIX B

Summary of Quality Control Test Results

FINAL TEST RESULT SUMMARY

Signal Conditioner SN Sensor SN	002 015	003 008	004 010	005 006	006 005	007 009	009 014
Insulation Resistance (megohms)	>900	>900	>900	>900	>900	>900	>900
Clipping Level (VDC)	5.364	5.350	5.367	5.372	5.375	5.367	5.373
Regulation 25 VDC To 31 VDC (MV)	+2 -4	+1 -1	+2 -0	-1 -4	+1 -3	+1 +1	+1 +1
Output Bias (VDC)	2.500	2.508	2.502	2.484	2.476	2.488	2.490
Equivalent input noise (db spl re .0002 μbar)	76	72	80	78	74	82	75
Input power (MA)	11.9	10.6	10.5	10.7	10.8	11.2	11.0
Weight (pounds)	.208	.208	.207	.210	.206	.206	.205
Mechanical Dimensions (inches)							
A	*	*	*	*	*	*	*
B	*	*	*	*	*	*	*
C	*	*	*	*	*	*	*
D	*	*	*	*	*	*	*
E	.625	.634	.625	.624	.622	.622	.621
F	.248	.248	.249	.248	.248	.248	.249
G	.895	.895	.896	.893	.889	.891	.890
H	36.5	37.0	37.0	37.0	36.4	37.2	35.6

*Gage Measurements

For test methods see appendix TSS-5 372A No.4.

SIGNAL CONDITIONER INPROCESS TEST RESULT SUMMARY

Signal Conditioner SN	002	003	004	005	006	007	009
Selected Resitor Values (OHMS)							
R10	750	220	820	180	1000	430	390
R11	13000	13000	12100	13000	13000	13000	13000
R12	2200	2400	1200	2000	1800	2200	1500
Clipping Level (VDC)							
20°F	5.299	5.260	5.298	5.290	5.322	5.267	5.282
70°F	5.381	5.352	5.372	5.376	5.386	5.390	5.386
160°F	5.430	5.447	5.441	5.445	5.425	5.260	5.497
Bias Level (VDC)							
20°F	2.401	2.416	2.411	2.384	2.390	2.410	2.408
70°F	2.490	2.506	2.490	2.472	2.482	2.492	2.495
160°F	2.580	2.600	2.591	2.563	2.580	2.586	2.600
Regulation 25 VDC to 31 VDC (MV)							
20°F	+4 -3	+0 -0	+0 -0	+2 -2	+1 -3	+0 -0	+1 -0
70°F	+1 -4	+10 +7	+1 -0	+2 -1	+1 -2	+2 +1	+3 +1
160°F	+2 -2	+0 -2	+0 -3	+1 -2	+0 -4	+0 -1	-1 -2
Input Current No signal (MA)							
20°F	11.0	10.5	10.4	10.9	10.9	11.3	11.1
70°F	10.8	10.5	10.5	10.4	10.7	11.0	10.8
160°F	10.3	10.1	9.9	10.2	10.2	10.8	10.5
Input Current Clipping (MA)							
20°F	12.4	11.9	12.0	12.2	12.9	13.0	12.8
70°F	12.5	12.1	12.1	12.2	12.8	12.9	12.6
160°F	11.8	11.6	11.3	11.8	11.9	12.5	12.2
Sensor Current Source (MA)							
20°F	.450	.488	.405	.445	.428	.462	.434
70°F	.448	.493	.415	.448	.440	.471	.439
160°F	.462	.496	.420	.455	.440	.471	.439

Signal Conditioner SN	002	003	004	005	006	007	009
Noise Re Input (dbv)							
20°F	-114	-117	-114	-109	-113	-114	-114
70°F	-114	-117.5	-115	-107	-113	-115	-114
160°F	-110	-117	-114	-102	-109	-112	-113
Gain Range	39.2	39.2	39.3	39.0	39.2	39.1	39.2
(db)	62.0	62.1	62.1	61.6	62.2	62.0	62.2
Gain Stability re 70°F (db)							
20°F	-0.1	-0.1	-0.0	-0.1	-0.1	-0.1	-0.1
160°F	+0.1	+0.1	+0.0	+0.1	+0.2	+0.2	+0.1
Frequency Response 3 db points (Hz)							
20°F	48 4300	51 4200	47 4400	48 3800	44 4400	43 4200	45 3900
70°F	47 4200	46 4100	43 4500	49 3900	44 4300	43 4500	47 4000
160°F	47 4300	48 4400	44 4400	44 3900	50 4600	40 4500	43 4100

For test methods see TSS-2 372A No. 1.

SENSOR INPROCESS TEST RESULT SUMMARY

Sensor SN	005	006	008	009	010	014	015
Output Impedance (OHms)	1190	1420	1390	980	1260	1110	1240
Sensitivity at 250H (db re 1 v/µbar)	-103.9	-105.0	-105.0	-107.3	-108.0	-105.0	-105.2
Equivalent input noise (db spl re .0002 µbar)	84.2	84.6	85.0	87.8	87.5	85.2	83.4
Vibration sensitivity (Equivalent spl/g)							
A Axis							
31.5	95	95	100	105	105	94	105
63.0	94	92	100	106	105	94	104
125	97	100	108	108	109	100	104
250	98	96	107	109	111	102	106
500	96	96	106	110	111	102	107
1000	97	91	104	110	111	102	107
2000	92	95	104	110	112	102	108
4000	92	93	99	111	108	103	109
B Axis							
31.5	97	96	110	98	100	102	98
63.0	96	93	108	96	98	103	93
125	101	99	111	105	106	105	99
250	100	96	112	99	104	106	94
500	97	95	113	98	99	106	96
1000	94	94	113	95	94	107	96
2000	99	91	113	96	96	108	97
4000	100	97	115	103	102	108	95
C Axis							
31.5	110	111	109	111	107	108	
63.0	114	114	114	115	112	112	
125	118	118	117	118	116	116	
250	120	121	120	121	118	119	
500	121	122	121	121	119	120	
1000	122	123	121	121	120	121	
2000	122	123	122	122	121	121	
4000	122	123	122	123	122	122	

Sensor SN	005	006	008	009	010	014	015
Frequency Response 500 Hz to 4000 Hz (db)							
20^oF	±.25	±.25	±.25	±.10	±.20	±.20	±.10
70^oF	±.10	±.25	±.25	±.10	±.20	±.10	±10
160^oF	±.10	±.25	±.25	±.10	±.10	±.20	±.20
Frequency Response 3db point re 1 kHz (Hz)							
20^oF	110	130	130	100	120	140	130
70^oF	100	125	120	100	110	125	120
160^oF	98	105	110	92	100	110	100
Relative sensitivity A 1000Hz re 70^oF (db)							
20^oF	+0.3	+0.6	+0.5	0.0	0.0	-0.3	+1.0
160^oF	0.0	-0.8	+0.2	-0.2	+0.1	-0.3	0.0

For test methods see TSS-3 372A No. 1.

APPENDIX C

Qualification Test Results

Test Report No. NT-6009-11 No. of Pages 12

Report of Test on

TRANSITION DETECTOR SYSTEM, 372A

Qualification Tests

for

Bolt, Beranek & Newman, Inc.

Associated Testing Laboratories, Inc.

Burlington, Massachusetts 01803

Date December 13, 1968

	Prepared	Checked	Approved
By:	T. Jarek	M. Pelissier	D.C. Jensen
Signed	T. Jarek	M. Pelissier	D.C. Jensen
Date	12/16/68	12-16-68	12-16-68

Administrative Data

1.0 Purpose of Test:

To determine the effects upon the submitted Transition Detector System when subjected to a series of Qualification Tests in accordance with the referenced Specification and the Test Procedure of this Report.

2.0 Manufacturer:

Bolt, Beranek & Newman, Inc.
50 Moulton Street
Cambridge, Massachusetts

3.0 Manufacturer's Type or Model No.: 372A

4.0 Drawing, Specification or Exhibit: In accordance with written instructions from an Engineering Representative of Bolt, Beranek & Newman, Inc.

5.0 Quantity of Items Tested: One (1) Conditioner Portion of the System, S/N 004, Sensor Portion of the System, S/N 010

6.0 Security Classification of Items: Unclassified

7.0 Date Test Completed: November 27, 1968

8.0 Test Conducted By: Associated Testing Laboratories, Inc.
NEW ENGLAND DIVISION

9.0 Disposition of Specimens: Returned to Bolt, Beranek & Newman, Inc.

10.0 Abstract:

The submitted Transition Detector System was subjected to Sinusoidal Vibration over the frequency range of 20 to 2000 Hz at various levels of acceleration up to a maximum of 25g's. During the exposure, the Unit was operated by an Engineering Representative of Bolt, Beranek & Newman, Inc. Upon completion of the entire Vibration Test, the Unit was visually examined for evidence of physical damage and none was noted. It was reported by the Engineering Representative of

10.0 Abstract (continued)

Bolt, Baranek & Newman, Inc. that the Transition Detector System functioned satisfactorily.

The Transition Detector System was subjected to Random Frequency Vibration over the frequency range of 20 to 2000 Hz at an overall level of approximately 12g's rms. During the vibration, the Unit was monitored by Engineering Representatives of Bolt, Baranek & Newman, Inc. and it was reported that the System functioned satisfactorily. There was no visible evidence of physical damage noted as a result of the Random Frequency Vibration Test.

The Transition Detector System was subjected to an Acceleration Test at various levels of acceleration up to a maximum of 160g's. During the Acceleration Test, the Unit was operated by Engineering Representatives of Bolt, Baranek & Newman, Inc. and it was reported that the System functioned satisfactorily. There was no visible evidence of physical damage noted as a result of the Acceleration Test.

The Transition Detector System was subjected to a Shock Test with shock impacts ranging up to a maximum of 300g's. Each shock impact approximated a saw tooth in wave shape. During the Shock Test, the Unit was operated by Engineering Representatives of Bolt, Baranek & Newman, Inc. and it was reported that the System functioned satisfactorily. There was no visible evidence of physical damage noted as a result of the Shock Test.

LIST OF APPARATUS

Item	Manufacturer	Model No.	Accuracy	Calibration Date	Calibration Date Due
Vibration System	MB Electronics	C60	Freq.±2% Ampl.±5%	9-23-68	12-23-68
Accelerometer	Endevco Corporation	2215-E	±5%	9-3-68	12-3-68
Oscilloscope	Tektronix, Inc.	545B	±3%	10-30-68	1-30-69
Random System	Ling Electronics		±5%	11-11-68	12-11-68
Radial Accelerator	Associated Testing Laboratories, Inc. (Mfg. Div.)	AC-10000	N/A	N/A	Prior to Use
Electronic Counter	Hewlett-Packard	521A	±1 count	11-21-68	2-21-69
Electronic Counter	Computer Measurements Co.	201CN	±1 count	11-8-68	2-8-69
Shock Machine	Avco Corporation	Type 110 Model -3	N/A	N/A	Prior to Use
Shock Test Console	Associated Testing Laboratories, Inc.		±5%	9-16-68	12-16-68
Oscilloscope	Tektronix, Inc.	564	±3%	11-26-68	2-26-69
AC Voltmeter	Hewlett-Packard	400H	±1%	9-7-68	12-7-68
Wide Range Oscillator	Hewlett-Packard	200CD	±2%	10-15-68	1-15-69

LIST OF APPARATUS

Item	Manufacturer	Model No.	Accuracy	Calibration Date	Calibration Date Due
Decade Capacitor	Cornell Dublier	CDA5	±5%	12-13-67	12-13-69
Accelerometer	Endevco Corporation	2225	±5%	10-4-68	12-4-69

SINUSOIDAL VIBRATION TEST

TEST PROCEDURE

The submitted Transition Detector System was subjected to a Sinusoidal Vibration Test in accordance with written instructions of an Engineering Representative of Bolt, Baranek & Newman, Inc. The following is a description of the test procedure as it was performed.

The Transition Detector System was securely mounted to the Vibration Test Fixture which, in turn, was securely mounted to the Vibration Exciter. All wiring required for operating and monitoring was returned to the necessary equipment as required. The Transition Detector System was then subjected to vibration over the frequency range of 20 to 2000 Hz at an applied vibratory level of 0.8 inches d.a. or ±25g's, whichever was the limiting value. The frequency range of 20 to 2000 Hz was traversed logarithmically once at a rate of two octaves/minute.

The above Procedure was performed with the applied vibration acting along each of the three mutually perpendicular axes. The fixtured Transition Detector System is shown in Figure 1 mounted in the Z Axis.

Upon completion of each axis of vibration, the System was visually examined for evidence of physical damage and electrically operated by an Engineering Representative of Bolt, Baranek & Newman, Inc.

TEST RESULTS

There was no visible evidence of physical damage noted as a result of the Sinusoidal Vibration Test. It was reported by the Engineering Representative of Bolt, Baranek & Newman, Inc. that the System functioned satisfactorily throughout and following the Vibration Exposure.

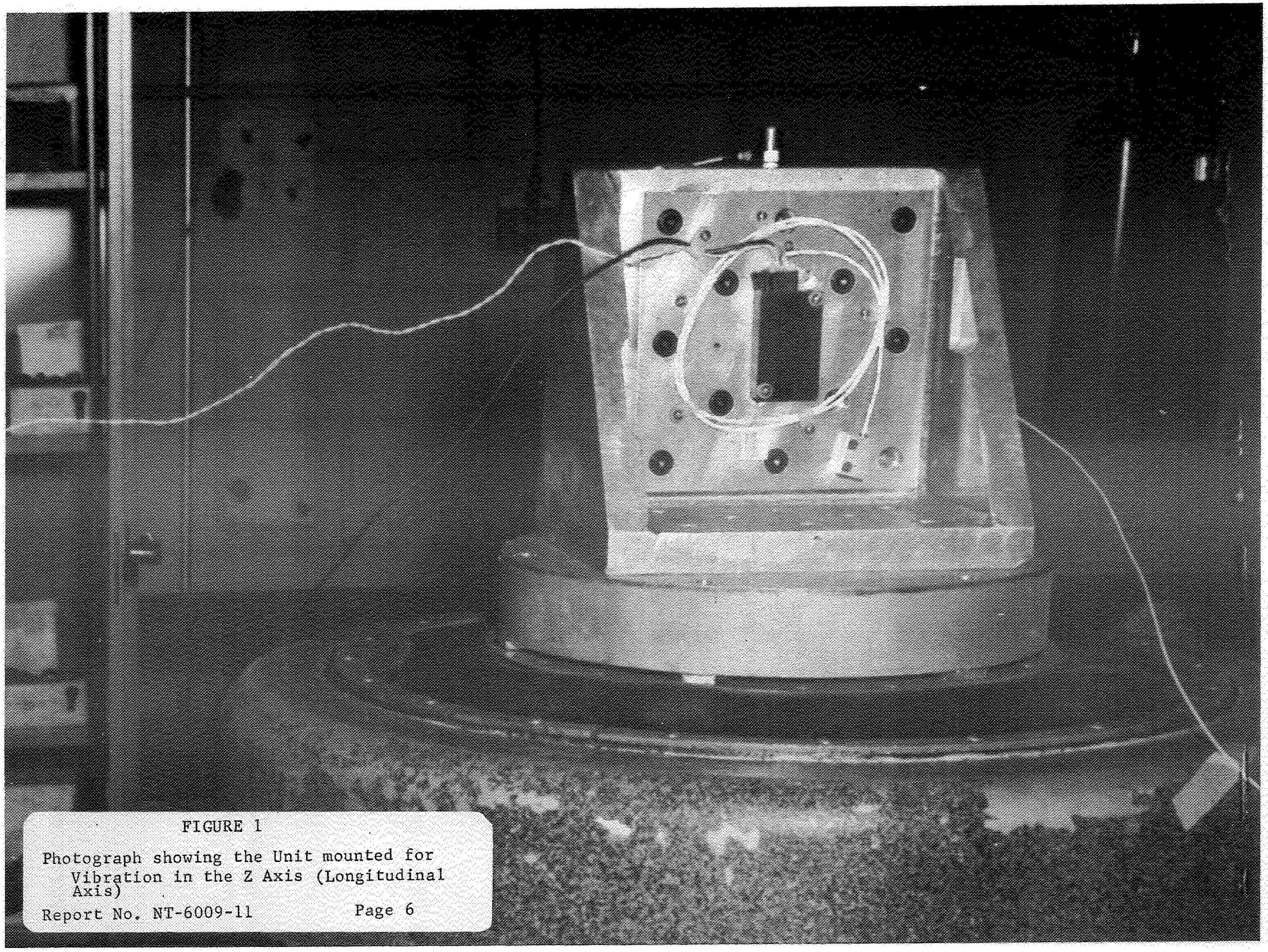


FIGURE 1

Photograph showing the Unit mounted for Vibration in the Z Axis (Longitudinal Axis)

RANDOM VIBRATION TEST

TEST PROCEDURE

The submitted Transition Detector System was subjected to a Random Frequency Vibration Test in accordance with written instructions from an Engineering Representative of Bolt, Baranek & Newman, Inc. The following is a description of the test procedure as it was performed.

The Transition Detector System was securely mounted to a Vibration Test Fixture which, in turn, was securely fastened to the Vibration Exciter. A Crystal Accelerometer was then mounted to the Vibration Test Fixture and was used to monitor the input to the Test Specimen. The Transition Detector System was then subjected to a Random Frequency Vibration Test at test levels as indicated in Table I as follows:

Table I

Frequency (Hz)	Spectral Density Level (g^2/Hz)	Overall Test Level
50 - 2000	0.073	12g's rms

The Transition Detector System was subjected to the above Vibration Test for a period of 60 seconds. This Procedure was performed with the applied vibration acting along each of the three mutually perpendicular axes.

Prior to subjecting the Transition Detector System to the Random Frequency Vibration Test, the Vibration System was equalized at the specified test levels. Equalization was accomplished by means of a System containing 80 parallel band pass filters with individual attenuators for spectrum shaping. Each filter had a maximum band width of 25 Hz. The overall g rms level was monitored by means of a True RMS Meter. Following equalization, the Transition Detector System was mounted to the Vibration Test Fixture and the System gain was increased to the desired test level.

RANDOM VIBRATION TEST

TEST PROCEDURE (continued)

Throughout the test, the Transition Detector System was electrically operated by an Engineering Representative of Bolt, Baranek, & Newman, Inc. Upon completion of each axis of vibration, the Test Specimen was visually examined for evidence of physical damage.

TEST RESULTS

There was no visible evidence of physical damage noted to the Transition Detector System as a result of the Random Frequency Vibration Test. It was reported by the Engineering Representative of Bolt, Baranek & Newman, Inc. that the Transition Detector System functioned satisfactorily throughout the Random Frequency Vibration Test.

ACCELERATION TEST

TEST PROCEDURE

The submitted Transition Detector System was subjected to an Acceleration Test in accordance with written instructions from an Engineering Representative of Bolt, Baranek & Newman, Inc. The following is a description of the test procedure as it was performed.

The Transition Detector System was securely fastened to the Acceleration Test Fixture which, in turn, was securely fastened to the beam of the Radial Accelerator. The Unit was placed in operation using a Battery supplied by the Engineering Representative of Bolt, Baranek & Newman, Inc. The Transition Detector System was then subjected to Radial Acceleration at the levels specified in Table II as follows:

Table II

Axis	Vibration Level
Longitudinal	160g's
Tangential and Normal	25g's

The speed of the Radial Accelerator was increased linearly to the speed required to obtain the specified acceleration force. The Test Specimen was subjected to the acceleration force for a period of 30 seconds. This Procedure was performed with the applied vibration acting along each direction of each of the three mutually perpendicular axes.

Upon completion of the entire Acceleration Test, the Transition Detector System was visually examined for evidence of physical damage and electrically checked by an Engineering Representative of Bolt, Baranek & Newman, Inc.

TEST RESULTS

There was no visible evidence of physical damage noted and it was reported by the Engineering Representative of Bolt, Baranek & Newman, Inc. that the Transition Detector System functioned satisfactorily.

SHOCK TEST

TEST PROCEDURE

The submitted Transition Detector System was subjected to a Shock Test in accordance with written instructions from an Engineering Representative of Bolt, Baranek & Newman, Inc. The following is a description of the test procedure as it was performed.

The Transition Detector System was securely fastened to the Shock Test Fixture, which, in turn, was securely fastened to the carriage of the Shock Machine. However, prior to subjecting the Unit to the Shock Test, the System was calibrated to obtain the desired shock wave form at the levels as specified. The Transition Detector System was subjected to a total of six shock impacts, one shock acting in each direction of each of the three mutually perpendicular axes. The wave form of each impact approximated a saw tooth having a peak magnitude and time duration as specified in Table III.

Table III

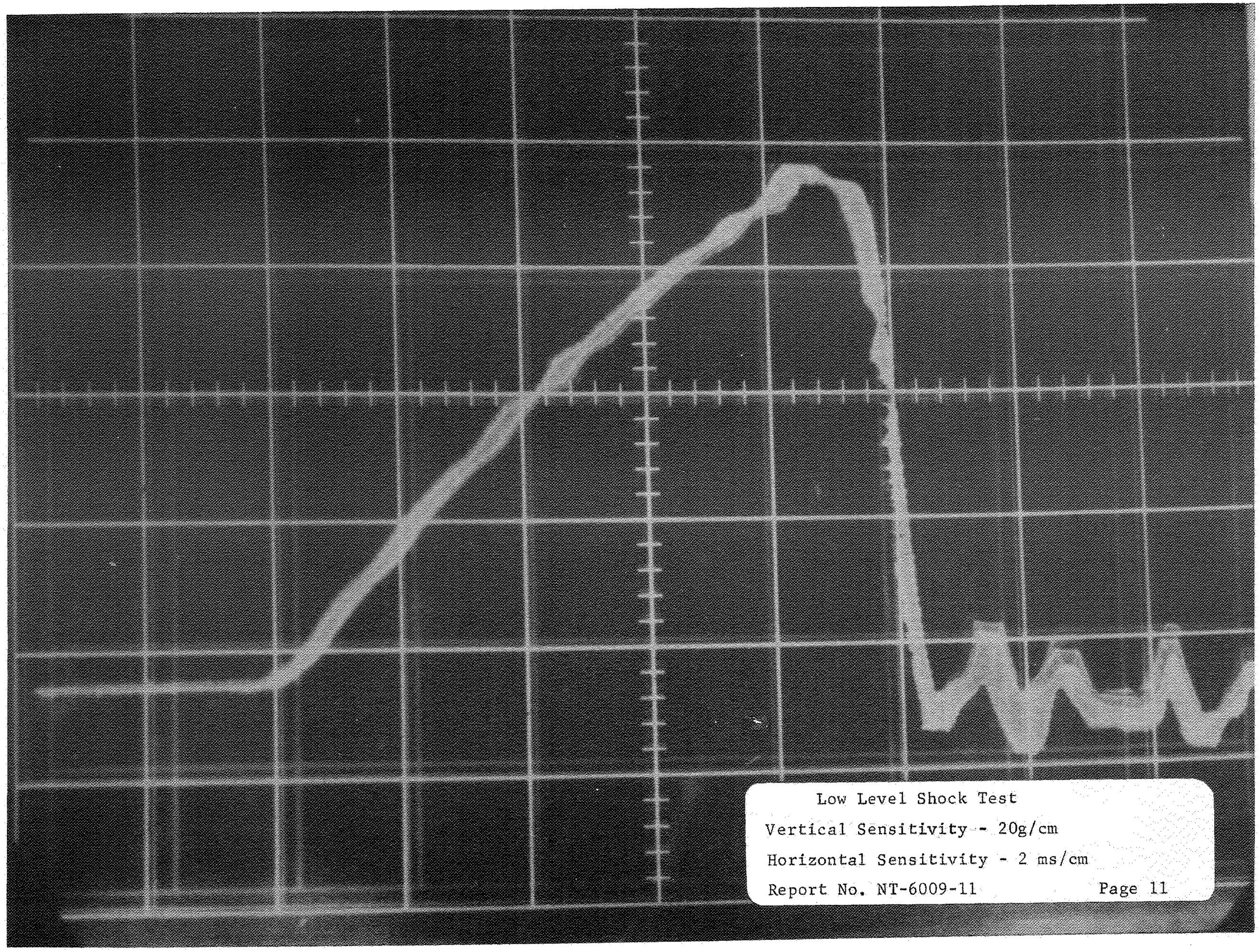
Axis	G Level	Time Duration
Normal and Tangential	80g's	10 milliseconds
Longitudinal	300g's	10 milliseconds

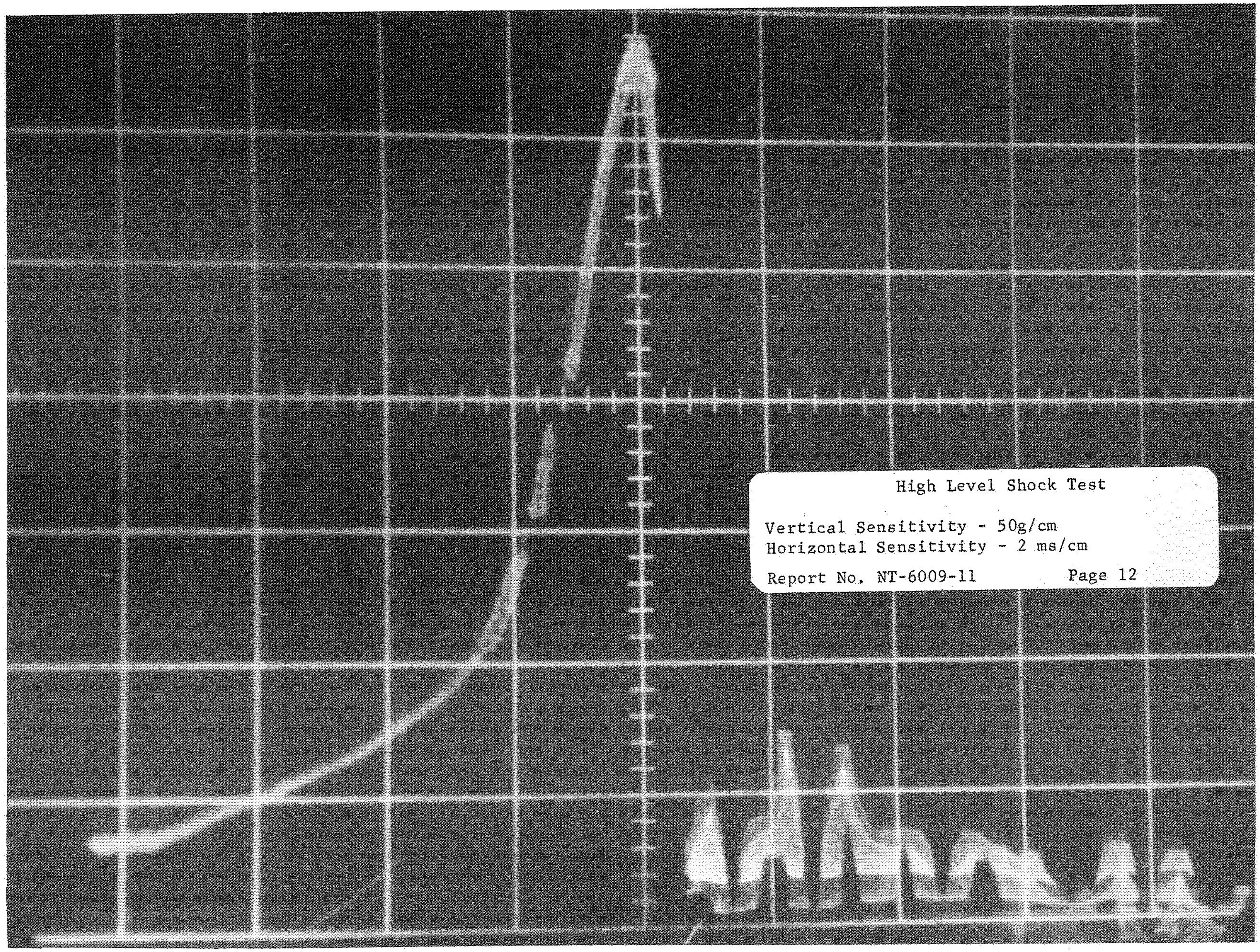
The Shock Test for the High Level Shock Impact was performed on a best effort basis.

During each shock impact, the Transition Detector System was operated by an Engineering Representative of Bolt, Baranek & Newman, Inc. Upon completion of the entire Shock Test, the Transition Detector System was visually examined for evidence of physical damage.

TEST RESULTS

There was no visible evidence of physical deterioration noted, and it was reported by the Engineering Representative of Bolt, Baranek & Newman, Inc. that the Transition Detection System functioned satisfactorily.


Low Level Shock Test
Vertical Sensitivity - 20g/cm
Horizontal Sensitivity - 2 ms/cm
Report No. NT-6009-11
Page 11


High Level Shock Test
Vertical Sensitivity - 50g/cm
Horizontal Sensitivity - 2 ms/cm
Report No. NT-6009-11
Page 12